Contents

[TOC \o "1-4" \h \z \t "EndNote Bibliography Title,1"]**Figures**

Tables

3.7.2 Groundwater and Surface Water Quality

3.7.2.1 Introduction

The proposed mine could potentially impact groundwater and surface water quality in several ways. The exposure of the mined rock to water and oxygen, inside the mine as well as in stockpiles prior to processing, can create elevated pH and high concentrations of dissolved metals. After processing, the tailings would be transported for disposal into the tailings storage facility. Seepage from the tailings has the potential to enter underlying aquifers and impact groundwater quality. In addition, contact of surface runoff with mined ore, tailings, or processing areas has the potential to impact surface water quality.

This section contains analysis of: existing groundwater and surface water quality; results of a suite of geochemical tests on mine rock; predicted water quality in the block-cave zone and potential exposure pathways, including the potential for a lake to form in the subsidence crater; impacts to groundwater and surface water from tailings seepage; impacts to surface water from runoff exposed to tailings; impacts to assimilative capacity of perennial waters; impacts to impaired waters; whether chemical added during processing would persist in the tailings storage facility; the potential for asbestiform minerals to be present; and the potential for naturally occurring radioactive materials to be present. Some additional details not discussed in detail here are captured in the project record [ADDIN EN.CITE <EndNote><Cite><Author>Newell</Author><Year>2018</Year><RecNum>25155</RecNum><DisplayText>(Newell and Garrett 2018)</DisplayText><record><rec-number>25155</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1545183978">25155</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Emily Newell</author><author>Chris Garrett</author></authors></contributors><titles><title>Water Resource Analysis: Assumptions, Methodology Used, Relevant Regulations, Laws, and Guidance, and Key Documents</title><secondary-title>Process memorandum to file</secondary-title></titles><dates><year>2018</year></dates><pub-location>Phoenix, Arizona</pub-location><publisher>SWCA Environmental Consultants. August 8</publisher><urls></urls><electronic-resource-num>110832</electronic-resource-num></record></Cite></EndNote>].

3.7.2.2 Analysis Methodology, Assumptions, and Uncertain and Unknown Information

Analysis Area

The analysis area is shown in figure 3.7.2-1 and encompasses all areas where groundwater or surface water quality changes could potentially occur due to the proposed project and alternatives. This includes the block-cave zone, each alternatives tailings footprint, aquifers downgradient from each tailings facility, and downstream surface waters.

Figure 3.7.2-1. Analysis area for groundwater and surface water quality

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Geochemistry Modeling Process

All tailings storage facilities—including filtered tailings—lose water to the environment in the form of seepage that drains by gravity over time. This seepage into groundwater is the primary source of potential water contamination from the project and has the potential to affect the quality of underlying aquifers as well as downstream surface waters fed by those aquifers. The water quality of tailings seepage reflects a mixture of different water sources used in the mining process (see figure 3.7.1-X) as well as geochemical changes that occur over time within the tailings storage facility and changes that occur as seepage moves downgradient through the aquifer.

Modeling the water quality changes caused by seepage from the tailings storage facility[1] requires a series of interconnected analyses, as shown on figure 3.7.2-2. These analyses include:

- The amount of water that must be removed from the block-cave zone during operations to allow mining. This is estimated using the **groundwater flow model** discussed in detail in section 3.7.1.

- The geochemical changes of the groundwater within the underground block-cave zone caused by the interaction of exposed rock surfaces to water and oxygen. These changes are estimated using a **block-cave geochemistry model**.

- The tailings slurry that leaves the processing facility is a mix of tailings and process water. As the tailings are deposited in the tailings storage facility, some process water is collected in the recycle pond and sent back to the West Plant Site, but some process water stays trapped in the pore space of the tailings (this is known as "entrainment"). ~~Eventually~~ Within X years it is expected/possible that some of this water can seep or drain out of the tailings facility. The water quality at various locations in the tailings facility is estimated using a **tailings solute geochemistry model**[2].

- ~~Some~~ Approximately X amount of the tailings that are deposited in the tailings storage facility would remain saturated indefinitely with little possibility of oxidation occurring. However, within the embankment and beach areas, sulfide-containing minerals in the tailings would be exposed to oxygen over time, which would cause geochemical changes. These changes are estimated using the **embankment sulfide oxidation model**.

- A wide variety of engineered seepage controls are in place to intercept and collect entrained water that seeps out of the tailings facility, but despite these controls ~~some~~ approximately X amount of seepage is still expected to ~~still~~ enter~~s~~ the environment. The effectiveness of engineered seepage controls is estimated using a variety of **tailings seepage models**.

- The seepage not captured and entering the environment causes water quality changes in the downgradient aquifers and eventually in surface waters fed by those aquifers. The changes in groundwater and surface water quality are estimated using a series of **bypass seepage mixing/loading models**.

Commented [CG2]: Water balance figure from section 3.7.1

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[1] For details of the geochemistry modeling workgroup formed to direct and review the water quality modeling, see Newell and Garrett 2018.

[2] The term "solute" refers to substances that are dissolved in water, such as metals like arsenic or selenium, or inorganic molecules like sulfate or nitrate.

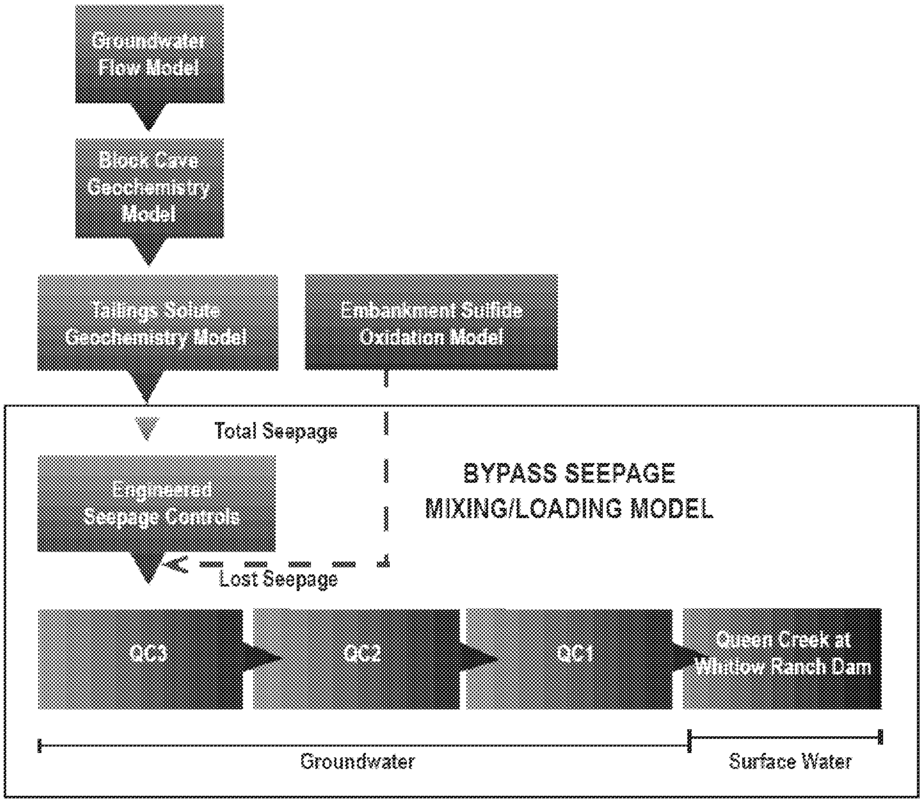

Figure 3.7.2-2. General components and process flow for water quality modeling analysis

Commented [CG4]: Need to change "Engineered Seepage Controls" to say "Engineered Seepage Controls (Tailings Seepage Models)"

Assumptions, Uncertain and Unknown Information for Geochemistry Models

BLOCK-CAVE GEOCHEMISTRY MODEL

Modeling Details

Water collects in the sump of the block-cave zone during operations and is derived from several sources, including:

- Groundwater inflow from the Apache Leap Tuff,
- Groundwater inflow from the deep groundwater system,
- Blowdown water from ventilation and cooling systems, and
- Excess mine service water.

A block-cave geochemistry model was constructed to blend these flows and their associated chemical composition over the time of operation of the mine (cite Eary 2018f). Groundwater flow modeling was used to assign the flow rate for groundwater inputs (cite WSP 2019). The rate of supply of blowdown water from ventilation systems is based on the overall water balance for the mine (cite WestLand Resources 2018).

Apache Leap Tuff and deep groundwater chemistries are based upon analysis of site groundwater samples. The chemical composition of blowdown water is based upon analysis of Central Arizona Project water and groundwater sourced from the Arizona Water Company (cite AWC 2016). Resolution Copper projects this blended water to be comprised of 25% Central Arizona Project water and 75% Arizona Water Company water. Owing to evaporation associated with cooling, this water mixture is concentrated to an assumed value for total dissolved solids of 2,500 mg/L.

Chemical weathering of wall rock and uneconomic mineralized fractured rock in the collapsed block cave zone are assumed to not supply any chemical load to the sump water; this assumption is discussed in more detail below. Where?

Commented [BM5]: Please identify where in the below

The model timeframe is 41 years and ends with the cessation of mining. Inflows to the block cave sump vary over time, but their chemical composition does not. The mixed waters reporting to the sump from their individual sources are equilibrated with any chemical precipitates that are oversaturated and likely to precipitate from solution. This precipitation of solids removes chemical mass from the mixed water. Results for model year 41, at the end of mining, are reported below in Table 3.7.2-1. What do these numbers look like at year 1, 5, 10, 15, 20, etc – why just look at year 41?

Table 3.7.2-1. Modeled Block Cave Sump Water Chemistry

Constituent	Eary Block Cave Geochemistry [redacted] Predicted Concentrations (mg/L)	Hatch Block Cave Geochemistry [redacted]) Predicted Concentrations (mg/L)	Arizona Aquifer Water Quality Standard Unit?	AZ Surface WQS?
Ca	237	434	-	
Mg	63	147	-	
Na	130	181	-	

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K	28	85	-	
Cl	46	85	-	
HCO3	114	19.9	-	
SO4	934	2247	-	
SiO2	22.4	17	-	
F	2.3	Not reported	4	
N	0.8	Not reported	-	
Al	0.0857	9.3	-	
Sb	0.0047	**0.035**	0.006	
As	0.0227	0.013	0.05	
Ba	0.0199	0.02	2	
Be	0.0003	**0.036**	0.004	
B	0.342	0.48	-	
Cd	0.0008	**0.19**	0.005	
Cr	0.0027	**0.241**	0.1	
Co	0.0063	2.72	-	
Cu	0.0158	141	-	
Fe	0.0025	0.1	-	
Pb	0.005	**0.088**	0.05	
Mn	0	14.2	-	
Hg	Not reported	0.018	0.002	
Mo	0.0135	0.000012	-	
Ni	0.0076	**2.5**	0.01	
Se	0.0051	**0.5**	0.05	
Ag	0.0039	0.165	-	
Tl	**0.0043**	**0.009**	0.002	
Zn	0.221	8.2	-	
pH s.u.	8.58	5.05	-	
TDS	1528	Not reported	-	

Modeled concentrations that are above Arizona aquifer water quality standards are show in boldface and shaded.

Dash indicates no Arizona numeric aquifer water quality standard exists for this constituent

Assumptions, Uncertain and Unknown Information

The block cave geochemistry model, like all models, necessarily includes assumptions in its effort to forecast future conditions. Assumptions are made to constrain model components that cannot be conclusively known and therefore represent uncertainty in the model results. The key assumptions in the block cave geochemistry model and their potential implications are described below.

Assumption: Apache Leap Tuff, Deep Groundwater, Central Arizona Project, and Arizona Water Company Water Chemistry Remains Constant

This assumption of the quality of incoming waters is unavoidable and depends on currently available measurements. Although deep groundwater, with its very long residence times (cite Montgomery 2016) is unlikely to vary in the future, Apache Leap Tuff, Central Arizona Project, and Arizona Water Company water, particularly Central Arizona Project water, may become more concentrated in response to lower future precipitation rates that produce longer residence times. These longer times can allow minerals contacting groundwater (Apache Leap Tuff, Arizona Water Company) to dissolve to a greater extent and increase concentrations. Central Arizona Project water is derived from the Colorado River drainage and subject to varying amounts of evaporative concentration and may also vary.

Using Arizona Water Company water as a surrogate for the future water supply is a reasonable assumption, as the Desert Wellfield would pump groundwater from the same general aquifer (East Salt River Valley). The future availability of Central Arizona Project water for mixing is an uncertainty, but both sources of water are very similar in composition and this is unlikely to have a major effect on outcomes.

The net effect of future changes in source water quality could be a potential slight increase in the predicted concentration of sump water quality.

Assumption: Weathering products from produced ore, prior to removal from the block cave zone remain with the ore and report to the tailings storage facility.

Ore will chemically weather (oxidize) in the hot, oxygenated, humid environment of the block-cave zone. Depending on the extent to which this ore contacts any inflowing groundwater, blowdown, or mine service water, some of the weathering products might report to the sump water, become incorporated into the process water stream, and ultimately report to the tailings storage facility as part of the tailings slurry. The model assumes that all chemical weathering products that are calculated to accumulate on ore are retained on the ore, pass through metallurgical processing, and report to the tailings storage facility. This simplifying assumption does not compromise the chemical loading to the tailings storage facility and the water resource impacts from the tailings storage facility that are subsequently modeled, as both the sump and ore moisture would become incorporated into the process stream.

Assumption: Chemical weathering of wall rock and uneconomic mineralized fractured rock in the collapsed block cave are assumed to not supply any chemical load to the sump water.

Eary (2018f) assumes that uneconomic fractured rock in the collapsed zone of the block cave does not contact oxygen, either during the typical 15-year period of mining of a given panel, or afterward. After a panel is mined, Eary (2018f) assumes that engineered controls of ventilation isolate the finished panel from oxygen. In panels being actively mined, oxygen is assumed to not migrate upward through the collapsed panel. This view of the ability of oxygen to pervade the panels has evolved since original submittal of the GPO; earlier modeling (cite Hatch 2015, cite Resolution Copper 2016 [Appendix R]) assumed oxygen would be present, and assumed that the rock in the collapsed zone would chemically weather. The following lines directly conflict with the above. If both approaches are reasonable then it is correct and prudent to apply the results of a model that assumes weathering and oxidation would be present or subsequent calculations will likely not be protective

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Modeled water quality for the two approaches differs substantially (see Table 3.7.2-1). The Hatch (2015) model estimates concentrations for dissolved chemical constituents that are higher than Eary (2018f). There is no conclusive evidence that supports either approach; both approaches are reasonable interpretations. The difference between the two approaches can be viewed as representing uncertainty in future water quality not only of the sump water that contributes to tailings storage facility seepage, but also the potential post-mining water quality in the block-cave zone; together they represent the range of likely impact.

TAILINGS SOLUTE GEOCHEMISTRY MODEL

Modeling Details

The water balance for the mine is complex, with multiple sources and recycling loops, and how these sources mix forms the fundamental basis for predicting the water quality in the tailings facility. The water balance differs for each tailings alternative [ADDIN EN.CITE ADDIN EN.CITE.DATA]. Chemical loading inputs are applied to each water source, and the resulting water quality is calculated with a mixing model (PHREEQC) for the entire operational life of the mine, with a different analysis conducted for each alternative [ADDIN EN.CITE ADDIN EN.CITE.DATA]. Water quality is modeled for six different locations:

- the mixture of water entering the West Plant Site;
- the PAG recycled water pond; the NPAG recycled water pond (not applicable to Alternative 4-Silver King);
- the water within the pore space of the tailings embankment;
- the seepage collection ponds; and
- the seepage lost to underlying aquifers not captured by the seepage collection ponds.

The tailings solute geochemistry model determines the chemistry of all water and chemicals reporting to the tailings storage facility, and the degree of evaporative concentration. It produces estimates of dissolved constituent concentrations in the tailings storage facility, a portion of which is lost seepage that is used in modeling impacts to downgradient water resources. The tailings solute geochemistry model results are strongly affected by the water balance for the tailings storage facility, which provides flows for the various components reporting to the tailings storage facility and accommodates for evaporative loss. This loss is used in the tailings solute geochemistry model to concentrate dissolved chemical constituents.

Assumptions, Uncertain and Unknown Information

The chemical quality of tailings storage facility seepage is directly linked to:

- the chemical composition of sump water pumped from the mine block-cave zone, and
- the chemical weathering products developed on ore before milling.

These components are estimated by the block-cave geochemistry model (cite Eary 2018f; cite Hatch 2015). As noted previously, estimates of the chemical composition of sump water are strongly affected by the assumed presence or absence of oxygen in the block-cave zone. In general, the concentration of chemical constituents under the oxygenated condition are significantly greater than the oxygen-free assumption. This uncertainty in the block-cave geochemistry model extends to the chemical loading in the tailings solute geochemistry model as well.

EMBANKMENT SULFIDE OXIDATION MODEL

Modeling Details

During operations, the tailings that are most likely to cause water quality problems from oxidation of sulfide minerals—the PAG tailings—would be kept in a subaqueous state with an overlying water cap to prevent oxygen from reaching and interacting with the tailings. During closure, the water cap would gradually be replaced with a cover of NPAG tailings and a reclamation cover to achieve the same result. The fine-grained tailings on the interior of the facility are expected to exhibit a low vertical permeability and a high moisture content, and oxygen is not expected to penetrate the tailings at rates sufficient to affect seepage chemistry for hundreds of years [ADDIN EN.CITE <EndNote><Cite><Author>Wickham</Author><Year>2018</Year><RecNum>25268</RecNum><DisplayText>(Wickham 2018)</DisplayText><record><rec-number>25268</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546307887">25268</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Matt Wickham</author></authors></contributors><titles><title>Prediction of tailings seepage water chemistry influenced by tailings weathering processes</title><secondary-title>Technical memorandum</secondary-title></titles><dates><year>2018</year></dates><pub-location>South Jordan, Utah</pub-location><publisher>Rio Tinto. August 23</publisher><urls></urls><electronic-resource-num>110759</electronic-resource-num></record></Cite></EndNote>].

However, the embankments of the NPAG tailings facility are constructed of well-drained cyclone sands. The same is true of the entirety of the filtered tailings facility (Alternative 4-Silver King). Oxygen would be able to enter these areas and react with sulfide minerals over time. The embankment sulfide oxidation model determines the chemical quality of seepage derived from the oxidation occurring in the tailings embankment for the 41 years of operation and an additional 204-year post-closure period [ADDIN EN.CITE <EndNote><Cite><Author>Wickham</Author><Year>2018</Year><RecNum>25268</RecNum><DisplayText>(Wickham 2018)</DisplayText><record><rec-number>25268</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546307887">25268</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Matt Wickham</author></authors></contributors><titles><title>Prediction of tailings seepage water chemistry influenced by tailings weathering processes</title><secondary-title>Technical memorandum</secondary-title></titles><dates><year>2018</year></dates><pub-location>South Jordan, Utah</pub-location><publisher>Rio Tinto. August 23</publisher><urls></urls><electronic-resource-num>110759</electronic-resource-num></record></Cite></EndNote>].

Assumptions, Uncertain and Unknown Information

Chemical loading is calculated using theoretical concepts regarding oxygen movement into the tailings that make up the embankment, and an experimentally-derived rate equation for the oxidation of sulfide minerals. The rate equation's validity is supported by field and laboratory testing, and the movement of oxygen is supported by literature-based studies; both assumptions are considered reasonable for the estimate of embankment seepage water quality.

TAILINGS SEEPAGE MODELS

Modeling Details

Management of water in the tailings storage facility must accomplish a variety of outcomes. For structural integrity, it is desirable to allow water to leave the NPAG tailings storage facility and the tailings embankment in the form of seepage (see section 3.10.1 for a further discussion of tailings stability). However, it is undesirable to allow that seepage to enter downstream aquifers or surface waters in amounts that can cause water quality problems. For PAG tailings, which tend to generate the worst seepage water quality, not only is it undesirable to allow seepage from PAG tailings to enter the environment but it is also necessary to maintain saturation of the PAG tailings to prevent oxidation.

Each alternative would use a specific set of engineered seepage controls that are built into the design in order to accomplish these goals. These include such controls as liners, blanket and finger drains, seepage collection ponds, and pumpback wells. The specific controls incorporated into each alternative design are described in section 3.7.2.4.

For a given tailings storage facility, estimates have been made of the "total seepage" and the "lost seepage". Total seepage is all water that drains from the tailings storage facility by gravity. Lost seepage is seepage that is not recovered with the engineered seepage controls. Lost seepage is assumed to discharge to the environment.

All alternative designs use a strategy of layering on engineered seepage controls to reduce the amount of lost seepage to acceptable levels. Some of these controls, such as foundation preparation, liners, drains, and seepage collection ponds, are implemented during construction of the facility. Other controls, such as auxiliary pump back wells, grout curtains, or additional seepage collection ponds, would be added as needed during operations depending on the amounts of seepage observed and the observed effectiveness of the existing controls.

The amount of seepage entering the environment is modeled in a variety of ways, depending on alternative (cite KCB 2019). Common to all of these models is that the engineered seepage controls described in section 3.7.2.4 are assumed to be in place, and the combined effectiveness of the layered engineered seepage controls is a key assumption in the ultimate predicted impacts to water.

The level of engineered seepage controls for each alternative was assigned based on practicability and initial modeling estimates of the "allowable seepage" (cite Gregory and Bayley 2108e). Allowable seepage is the estimated quantity, as a percentage of total seepage, that can be released without resulting in groundwater concentrations that are above Arizona aquifer water quality standards, or surface water concentrations that are above Arizona surface water quality standards. The allowable seepage target is a significant driver for the design of each facility; engineered seepage controls were increased in the design as needed to limit lost seepage.

Commented [BM7]: please add AZ SWQS to above table to support ths paragraph

Assumptions, Uncertain and Unknown Information – All Alternatives

Engineered seepage controls incorporated into the tailings storage facility design serve to assure geotechnical stability/safety and recover a percentage of the total seepage released, in order to meet the limits of allowable seepage. The bypass seepage mixing/loading model is reliant on the amount of lost seepage, and therefore reliant on both the feasibility and effectiveness of the engineered seepage controls. This represents a source of uncertainty in the modeling results and the environmental impacts described in section 3.7.2.4, particularly where there is limited characterization of site conditions or materials.

Assumptions, Uncertain and Unknown Information – Alternatives 2 and 3

Estimates of Total and Lost Seepage

For Alternatives 2 and 3, total seepage was estimated during the initial design phase using a one-dimensional, unsaturated flow model (cite KCB 2018a, KCB 2018b). Total seepage estimates start with a water balance calculation of flow through the tailings during full buildout. The water balance is based on assumptions about weather (precipitation and evaporation), and assumptions about area and depth of the tailings. Assuming full-buildout conditions overestimates seepage initially and during drain-down, however, it is a valid assumption for much of the post-closure life of the tailings storage facility.

The total seepage estimates were later incorporated into a three-dimensional steady-state flow model. The three-dimensional model was used to model the amount of this total seepage that would be captured by various engineered seepage controls, leaving some amount of lost seepage to enter the environment downgradient.

- For Alternative 2, total seepage was estimated at 2,132 acre-feet (2.6298 x 10^9 liters/yr) per year and lost seepage was modeled to be 194 acre-feet (2.393x10^8 liters/yr) per year with an initial suite of engineered seepage controls (cite Groenendyk and Bayley 2018b), and 21 acre-feet (2.59X10^7 liters/yr) per year with an enhanced suite of engineered seepage controls (cite Groenendyk and Bayley 2019).
- For Alternative 3, total seepage was estimated at 728 acre-feet (8.98x10^8liters/yr) per year and lost seepage was modeled to be 116 acre-feet per year (1.431ex10^8 liters/yr) with an initial suite of engineered seepage controls (cite Groenendyk and Bayley 2018b), and 3 acre-feet (3.7x10^6 liters/yr) per year with an enhanced suite of engineered seepage controls (cite Groenendyk and Bayley 2019).

Uncertainties in Engineered Seepage Controls

For Alternatives 2 and 3 it is assumed that all alluvial channels starting below the site footprint would be removed or excavated during construction, so all seepage would flow through lower conductivity bedrock before entering the alluvial channels of Roblas Canyon, Potts Canyon and Queen Creek. Incomplete removal of alluvial channels within the interior of the tailings storage facility would allow for faster transport of seepage towards the Queen Creek alluvium and Whitlow Ranch dam. This is only a possibility within the interior of the tailings storage facility, as finger and blanket drains would be placed to enhance seepage under NPAG tailings embankment. The seepage model also does not account for possible preferential flow along minor faults in the bedrock underlaying the tailings storage facility footprint.

The three-dimensional stead-state model assumes ideal placement of all pump-back wells and dams and grout curtains. Pump back wells might not be located in ideal locations and therefore allow more flow to escape than modeled.

Commented [BM8]: Why? What can be done to better place the pumpback wells?

The seepage efficiency as modeled is 99 percent for Alternative 2 and 99.5 percent for Alternative 3. This efficiency could be difficult to achieve. As a comparison, the seepage estimate of 20.7 acre-feet (2.5533x10^7 liters/yr) per year is about 25 times less than the seepage that would be estimated with the EPA (1999) method for a fully lined facility (not including pump back wells, dams or grout curtains). To achieve this efficiency, the number of pump back wells is large (11 wells located at the seepage collection dams, and an additional 21 auxiliary pump back wells located beyond the seepage collection dams) and the length of the grout curtain for both alternatives (approximately 7.5 miles) would be larger by a factor of 10 than any other grout curtain in the United States.

Commented [BM9]: Are there structural or integrity concerns with the size of the grout curtain or the number and ability of pumpback wells to achieve this forecasted result?

Assumptions, Uncertain and Unknown Information – Alternative 4

Estimates of Total and Lost Seepage

For Alternative 4-Silver King, total seepage was estimated during the initial design phase using a one-dimensional, unsaturated flow model (cite KCB 2018c). Total seepage estimates start with a water balance calculation of flow through the tailings during full buildout. The water balance is based on assumptions about weather (precipitation and evaporation), and assumptions about area and depth of the tailings. Assuming full-buildout conditions overestimates seepage initially and during drain-down, however, is a valid assumption for much of the life of the tailings.

Unlike Alternatives 2 and 3, there is limited information on the hydrology and geology of the proposed Silver King tailings location and constructing a similar three-dimensional steady-state flow model is not feasible. The efficiency of seepage capture was estimated instead based on professional judgment of the design engineers and an understanding of the potential flow pathways for seepage.

- For Alternative 4, total seepage was estimated at 80 acre-feet (9.868e+7 liters/yr) per year (includes NPAG, PAG, and collection pond seepage), and lost seepage was modeled to be 17 acre-feet(2.097e+7 liters/yr) per year with an initial suite of engineered seepage controls (cite KCB 2019b), and 9 acre-feet (1.11e+7 liters/yr) per year with an enhanced suite of engineered seepage controls (cite KCB 2019b).

Uncertainties in Engineered Seepage Controls

Underdrains would collect seepage from the facility, and the alluvial channels where seepage would preferentially flow are relatively small and would cut off with seepage collection dams. However, foundation conditions at the site are largely undefined and introduce substantial uncertainty, as other flow paths could potentially bypass seepage controls. Control efficiencies were estimated as no greater than 80 percent for an initial suite of engineered seepage controls and no greater than 90 percent for an enhanced suite of engineered seepage controls (cite KCB 2019b).

Efficiency of seepage controls for Alternative 4 is based on professional judgment and may vary significantly depending on implementation. For example, the enhanced suite of engineered seepage controls uses targeted grouting of fractures, which can vary widely in efficiency based on field conditions.

Assumptions, Uncertain and Unknown Information – Alternative 5

Estimates of Total and Lost Seepage

For Alternative 5, total seepage estimates are based on an "Order of Magnitude" water balance estimated using a two-dimensional finite element model (SLIDE V7.0) (Golder 2018). The water balance is based on assumptions about weather (precipitation and evaporation), and assumptions about area and depth of the tailings. Assuming full-buildout conditions overestimates seepage initially and during drain-down, however, is a valid assumption for much of the life of the tailings. Foundation conditions at the site are undefined and introduce a large uncertainty in estimates of seepage and efficiency of engineered seepage controls. Thus, seepage can only be estimated to the closest order of magnitude.

The amount of lost seepage for Alternative 5 is calculated in a different manner than other alternatives. Much of the foundation consists of a deep alluvial aquifer associated with Donnelly Wash, which results in substantial seepage losses even with engineered seepage controls built into the facility. Therefore a downstream pumpback system is a key component of the engineered seepage controls. The amount of flow the alluvial aquifer is able to handle was estimated and a downstream pump back well system is expected to remove enough water to maintain the aquifer at equilibrium.

- For Alternative 5, total seepage was estimated at 3,930 acre-feet (4.8476e+9 liters/yr) per year~~,~~ including PAG and NPAG facility seepage (cite Golder 2018; cite Golder 2019). Lost seepage was modeled to be 1,317 acre-feet (1.6245e+9 liters/yr) per year with the pump back well system (cite Golder 2019), and 261 acre-feet (3.219e+8 liters/yr) per year with an enhanced suite of engineered seepage controls including the use of thin-lift deposition (cite Golder 2019).

Uncertainties in Engineered Seepage Controls

Seepage mitigation is of minor importance for Alternative 5, since the large volumes of groundwater flow in the substantial alluvial aquifer create ~~dilution, and~~dilution and are thus able to accept larger amounts of seepage. Thin lift deposition and pump back wells are used to control seepage. Efficiencies of those controls are estimates.

It should also be noted that the lost seepage value of 261 acre-feet is based on a reduced pumping amount from the pump back well system, and additional pumping could take place as needed.

Assumptions, Uncertain and Unknown Information – Alternative 6

Estimates of Total and Lost Seepage

For Alternative 6, total seepage estimates are based on two-dimensional steady-state finite element model (SEEP/W) (cite KCB 2019c) Total seepage estimates start with a water balance calculation of flow through the tailings during full buildout. The water balance is based on assumptions about weather (precipitation and evaporation), and assumptions about area and depth of the tailings. Assuming full-buildout conditions overestimates seepage initially and during drain-down, however, is a valid assumption for much of the life of the tailings.

The amount of lost seepage for Alternative 6 is estimated in two ways, both derived from the two-dimensional model. One estimate of lost seepage is the difference between these modeled seepage from the NPAG and PAG facilities, minus the amount of seepage modeled to be collected in the downstream seepage collection pond. A second estimate is derived directly from the modeled flux of water downstream of the seepage collection pond.

- For Alternative 6, total seepage was estimated at 1,870 acre-feet (2.3066e+9 liters) per year, including PAG and NPAG facility seepage (cite KCB 2019c). Lost seepage was modeled to range from 580 to 600 acre-feet (7.401e+8 liters) per year with a 70-foot deep grout curtain and a 20-foot deep pumpback well system installed at the seepage collection pond. Lost seepage decreased to 270 to 370 acre-feet (4.564e+8 liters) per year with a 100-foot deep grout curtain and 70-foot deep pump back well system, and to 70 to 180 acre-feet (2.22e+8 liters) per year with the pump back well system extended to a depth of 100 feet as well (cite KCB 2019c).

Uncertainties in Engineered Seepage Controls

Foundation conditions at the site are variable and undefined and introduce a large uncertainty in estimates of seepage and the engineered seepage controls. There is little information about potential faults which may create preferential flow path for seepage. Seepage mitigation includes a grout curtain to a depth of 100 feet. The practicality of a grout curtain and the efficiency of a grout curtain are difficult to estimate. Flaws in the grout curtain may allow larger volumes of seepage to reach downstream of the site.

Commented [BM10]: Is this a common concern?

BYPASS SEEPAGE MIXING/LOADING MODELS

Modeling Details

The water quality of the tailings seepage (estimated using the tailings solute geochemistry models), the changes in water quality from the embankment (estimated using the embankment sulfide oxidation model), and the predicted amounts of lost seepage from the facility (estimated using the tailings seepage models), are input into a series of bypass seepage mixing/loading models. These models predict the changes in aquifer water quality as lost seepage flows downgradient from each tailings storage facility. The bypass seepage mixing/loading model uses the Goldsim software package to calculate the mass balance and account for dilution from groundwater present in a series of connected mixing cells. The model framework is slightly different for each alternative; all models are run for the 41 years of operation and an additional 204 years post-closure.

- **Alternatives 2 and 3**. The mixing/loading model for Alternatives 2 and 3 estimates groundwater quality in five different mixing cells, starting with Robles Canyon and Potts Canyon, then flowing into Queen Creek (three mixing cells). The model ends at Whitlow Ranch Dam, where groundwater emerges as surface water ([ADDIN EN.CITE <EndNote><Cite><Author>Gregory</Author><Year>2018</Year><RecNum>25270</RecNum><DisplayText>(Gregory and Bayley 2018d)</DisplayText><record><rec-number>25270</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546367709">25270</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Chris Gregory</author><author>Tim Bayley</author></authors></contributors><titles><title>TSF Alternatives 2 and 3 - Near West: Life of Mine and Post-Closure Seepage Transport Modeling</title><secondary-title>Project #: 605.8207. Technical memorandum</secondary-title></titles><dates><year>2018</year></dates><pub-location>Tucson, Arizona</pub-location><publisher>Montgomery and Associates Inc. September 14</publisher><urls></urls><electronic-resource-num>110587</electronic-resource-num></record></Cite></EndNote>]. Background groundwater quality is derived from a well located adjacent to Queen Creek, using the median of nine samples collected between May 2017 and February 2018. Background surface water quality is derived from the median of 15 samples collected at Whitlow Ranch Dam between March 2015 and December 2017.
- **Silver King (Alternative 4)**. Even though this alternative is comprised of filtered tailings, some seepage is still expected to occur with Alternative 4, though a very small amount, compared with Alternatives 2, 3, 5 and 6. The downstream mixing model estimates groundwater quality in nine cells, which start with Potts Canyon, Silver King Wash, and Happy Camp Wash East and West, then flowing into Queen Creek (five mixing cells). The model ends at Whitlow Ranch Dam, where groundwater emerges as surface water [ADDIN EN.CITE <EndNote><Cite><Author>Gregory</Author><Year>2018</Year><RecNum>25271</RecNum><DisplayText>(Gregory and Bayley 2018a)</DisplayText><record><rec-number>25271</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546367885">25271</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Chris Gregory</author><author>Tim Bayley</author></authors></contributors><titles><title>TSF Alternative 4 - Silver King: Life of Mine and Post-Closure Seepage Transport Modeling</title><secondary-title>Project #: 605.8401. Technical memorandum</secondary-title></titles><dates><year>2018</year></dates><pub-location>Tucson, Arizona</pub-location><publisher>Montgomery and Associates Inc. September

14</publisher><urls></urls><electronic-resource-num>110588</electronic-resource-num></record></Cite></EndNote>]. Background groundwater and surface water quality are derived from the same sources as Alternatives 2 and 3.

- **Peg Leg (Alternative 5)**. The Peg Leg location is fundamentally different from Alternatives 2, 3, and 4 in that much of the facility overlies a large alluvial aquifer, resulting in relatively large seepage rates, compared with other alternatives. The downstream mixing model estimates groundwater quality in five cells along Donnelly Wash to the Gila River [ADDIN EN.CITE <EndNote><Cite><Author>Gregory</Author><Year>2018</Year><RecNum>25272</RecNum><DisplayText>(Gregory and Bayley 2018b)</DisplayText><record><rec-number>25272</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546368171">25272</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Chris Gregory</author><author>Tim Bayley</author></authors></contributors><titles><title>TSF Alternative 5 - Peg Leg: Life of Mine and Post-Closure Seepage Transport Modeling</title><secondary-title>Project #: 605.8302. Technical memorandum</secondary-title></titles><dates><year>2018</year></dates><pub-location>Tucson, Arizona</pub-location><publisher>Montgomery and Associates Inc. September 14</publisher><urls></urls><electronic-resource-num>110589</electronic-resource-num></record></Cite></EndNote>]. Background groundwater quality is derived from a single sample in September 2017 from a well located adjacent to Donnelly Wash. Background surface water quality is derived from a single sample in November 2018 from the Gila River at the confluence with Donnelly Wash.

- **Skunk Camp (Alternative 6)**. The Skunk Camp is similar to the Peg Leg location, with much of the facility overlying an alluvial aquifer associated with Dripping Spring Wash. The downstream mixing model estimates groundwater quality in five cells along Dripping Spring Wash to the Gila River [ADDIN EN.CITE <EndNote><Cite><Author>Gregory</Author><Year>2018</Year><RecNum>25273</RecNum><DisplayText>(Gregory and Bayley 2018c)</DisplayText><record><rec-number>25273</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546368295">25273</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Chris Gregory</author><author>Tim Bayley</author></authors></contributors><titles><title>TSF Alternative 6 - Skunk Camp: Life of Mine and Post-Closure Seepage Transport Modeling</title><secondary-title>Project #: 605.8501. Technical memorandum</secondary-title></titles><dates><year>2018</year></dates><pub-location>Tucson, Arizona</pub-location><publisher>Montgomery and Associates Inc. September 14</publisher><urls></urls><electronic-resource-num>110590</electronic-resource-num></record></Cite></EndNote>]. Background groundwater quality is derived from a single sample in November 2018 from a well located adjacent to Dripping Springs Wash. Background surface water quality is derived from a single sample in November 2018 from the Gila River at the confluence with Dripping Springs Wash.

A relatively straightforward mixing cell model is used to evaluate the impact to water, as shown in figure 3.7.2-2. Lost seepage from a given tailings storage facility alternative mixes with the flow of underlying groundwater in the first model cell. The flow of water and dissolved chemicals from this cell passes to the next cell downgradient and is combined with any other flows reporting to that cell. Flows are passed from one groundwater cell to the next until it discharges to a receiving surface water, which is the last cell in the model. At each step, the concentrations of chemical constituents are calculated. The model dimensions of the groundwater cells dictate the amount of dilution that is achieved on mixing with lost seepage; the larger the cells, the greater the diluting effect.

The tailings seepage models for each alternative described previously are primarily estimate of the amount of seepage over the life of the mine. The bypass seepage mixing/loading models also use a separate estimate of the amount of long-term seepage after closure, primarily derived from expected infiltration of precipitation. The seepage values used in the mixing/loading models to achieve the results described in section 3.7.2.4 are:

- Alternative 2. Life-of-mine seepage of 21 acre-feet per year (Groenendyk and Bayley 2019); post-closure seepage of 17 acre-feet per year (Gregory and Bayley 2018f).
- Alternative 3. Life-of-mine seepage of 3 acre-feet per year (Groenendyk and Bayley 2019); post-closure seepage of 25 acre-feet per year (Gregory and Bayley 2018f).
- Alternative 4. Life-of-mine seepage of 9 acre-feet per year (KCB 2019b); post-closure seepage of 15 to 32 acre-feet per year (Gregory and Bayley 2019; Wickham 2018). Note that unlike Alternatives 2, 3, 5, and 6, after closure seepage actually increases over time for Alternative 4, as the low moisture levels in the filtered tailings come to equilibrium with infiltration of precipitation.
- Alternative 5. Life-of-mine seepage of 261 acre-feet per year (Golder 2019); post-closure seepage of 258 acre-feet per year (Gregory & Bayley 2018b).
- Alternative 6. Life-of-mine seepage of 70-180 acre-feet per year (KCB 2019c); post-closure seepage of 258 acre-feet per year (Gregory & Bayley 2018c).

Assumptions, Uncertain and Unknown Information – All Alternatives

The uncertainties described for the block-cave geochemistry model, the tailings solute geochemistry model, and the embankment sulfide oxidation model also add to the uncertainty of the bypass seepage mixing/loading model.

A lack of site hydrogeological characterization strongly affects the size of the groundwater cells in the model and also limits knowledge of baseline water chemical composition. To the extent that the size of model cells may be smaller as a result of better hydrogeologic characterization, modeled concentrations will increase. Conversely, if cell sizes are adjusted upward, either modeled concentrations decrease, or lower levels of mitigation design can be incorporated. Specific issues for each alternative are discussed below.

Assumptions, Uncertain and Unknown Information – Alternatives 2 and 3

Although seepage reports to Potts and Roblas Canyons (the first mixing cells in the model), these cells do not have any substantial groundwater component. For the purposes of assessing impacts to groundwater quality, it is assumed that the first substantial groundwater appears in the first cell associated with the alluvial aquifer along Queen Creek (cell QC-3).

The hydrogeological characterization for this tailings location is based on a site-specific investigation, including drilling groundwater wells and performing pumping tests (Montgomery 2017b). Site investigation informed the seepage model; however, groundwater conditions must be interpolated between points of investigation, which increases uncertainty about groundwater flows. By necessity, the three-dimensional steady-state model (used to estimate lost seepage) and the seepage mixing model (used to estimate aquifer and surface water quality impacts) represent simplified versions of the actual site, and modeled flow paths, volumes, and velocities are approximations of actual conditions. Should groundwater volumes or flow rates be smaller than modeled, higher concentrations would occur than those modeled.

Assumptions, Uncertain and Unknown Information – Alternative 4

Similar to Alternatives 2 and 3, the mixing cell model for Alternative 4 is comprised of cells corresponding to flow in alluvial channels leading to the first substantial groundwater at Queen Creek. Washes with small alluvial channels are potential conduits for tailings seepage, however, do not necessarily contain native groundwater. The Happy Camp drainages have only very shallow alluvium, and a spring in lower Happy Camp Canyon is said to be fed by regional groundwater, not groundwater in the Happy Camp drainage alluvium. East and West Happy Camp drainages start underneath the tailings footprint, so don't collect or transfer substantial water from upstream. Thus, these washes are modeled as compartments in the mixing model, however, for the purposes of estimating impacts to aquifer water quality it is assumed that the first substantial groundwater appears in the first cell corresponding to the alluvial aquifer along Queen Creek (cell QC-1).

The general lack of site hydrogeological characterization strongly affects the outcome of the seepage mixing model for this alternative. Site groundwater conditions for Alternative 4 are not well defined and are estimated to be similar to conditions at the site for Alternative 2. The site sits across the Concentrator, Main and Conley Springs faults. These faults may cause seepage that is not flowing along alluvial channels to flow parallel to the faults, which may result in faster or more direct movement. This geologic uncertainty is reflected in the estimates for the efficiency of engineered seepage controls.

Modeling in Queen Creek assumes that seepage fully mixes across the full width of the Queen Creek alluvium. Should only partial mixing occur, this would also increase concentrations in parts of the alluvial aquifer. As noted for Alternatives 2 and 3, should groundwater volumes or flow rates be smaller than modeled, higher concentrations would occur than those modeled.

Assumptions, Uncertain and Unknown Information – Alternative 5

The general lack of site hydrogeological characterization strongly affects the outcome of the seepage mixing. Site groundwater conditions for Alternative 5 are not well defined, depth to groundwater, thickness, gradient and hydraulic conductivities of the aquifer are estimates based on geologic maps and literature (Golder 2018). Thus, concentrations after mixing with groundwater are rough estimates that may change depending on actual site conditions.

Modeling assumes that seepage fully mixes across the width of the tailings facility with groundwater in the Donnelly wash alluvium. Should only partial mixing occur, or preferential flow paths exist, this would also increase concentrations in parts of the alluvial aquifer and could change the travel velocity. Particularly, should the seepage not mix with the fully estimated saturated depth, higher concentrations would occur in the upper parts of the aquifer.

Both the background groundwater and surface water quality are based on single samples; a longer period of record could result in different background concentrations, which could change the analysis.

Assumptions, Uncertain and Unknown Information – Alternative 6

The general lack of site hydrogeological characterization strongly affects the outcome of the seepage mixing. Site groundwater conditions for Alternative 6 are not well defined, depth to groundwater, thickness, gradient and hydraulic conductivities of the aquifer are estimates based on geologic maps, literature and site visits (KCB 2019c). Thus, concentrations after mixing with groundwater are rough estimates that may change depending on actual site conditions.

The estimated lost seepage is the input for the mixing cell model and all seepage is assume to flow into the alluvium in Dripping Springs Wash. It is possible that not all seepage will be collected in the first Dripping Spring mixing cell, and/or continues to flow in the weathered Gila Conglomerate so that some seepage does not reach Dripping Spring Wash until further downstream, and thus concentrations in the first mixing cell may be lower than modeled.

Both the background groundwater and surface water quality are based on single samples; a longer period of record could result in different background concentrations, which could change the analysis.

OVERALL EFFECT OF UNCERTAINTIES ON THE MODEL OUTCOMES

As with all modeling, the modeling used to estimate water quality impacts for each alternative contains assumptions and uncertainty that limit the accuracy and reliability of the associated results.

Assumptions meant to provide greatest environmental protection

The model construction includes some intentional bias to skew results that produce a greater negative impact and therefore provide the greatest environmental protection. Examples include:

- The assumption that life-of-mine discharge from tailings storage facility remains at the highest levels associated with the drain down process, rather than decreasing over time. This maximizes the modeled chemical discharge from the tailings storage facility.
- The model does not consider any geochemical processes in the ground- and surface water flow that might lower concentrations. Examples include potential chemical precipitation of oversaturated solids, or adsorption of chemical constituents onto aquifer solids that can both lower concentrations in the water.
- For comparisons against surface water standards, median flow values were used which is appropriate when replicating baseflow. Concentrations during runoff events would be expected to be lower due to dilution from storm flows.
- Variations in hardness can change surface water quality standards for some metals, with increasing hardness resulting in a higher water quality standard; for the comparisons in section 3.7.2.4, the best available information on existing hardness was used (as calculated from calcium and magnesium concentrations).

Uncertainty of hydrogeologic framework

While substantial site investigation has been conducted at the Near West tailings location (Alternatives 2 and 3), the hydrogeologic framework is more uncertain for Alternatives 4, 5, and 6. Changes in the size of the aquifer and the amount of groundwater present in the aquifer can change the water quality results, potentially resulting in greater concentrations than those disclosed. However, the modeling relies on the best available hydrologic and geologic information and makes reasonable assumptions about aquifer conditions. Future hydrologic and geologic investigations at these locations would reduce this source of uncertainty.

Uncertainty of background water quality

Alternatives 2, 3, and 4 rely on background groundwater and surface water quality values based on a reasonable number of samples; this reflects the fact that hydrogeologic investigation of sites in the Superior basin has been ongoing since 2003. Alternatives 5 and 6 rely on single samples to establish background water quality, reflecting the fact that these sites were only identified recently during alternatives development. While limited, these samples still represent the best available water quality information for these locations. Continued sampling over time would reduce this source of uncertainty.

Uncertainty of block-cave oxidation

As described, two different models of the geochemistry of the block-cave zone have been conducted, one assuming that oxidation occurs (Hatch 2015) and one assuming it does not (Eary 2018f). The block-cave geochemistry model used as a basis for the water quality modeling (Eary 2018f) represents the current conception of the mechanics of block-caving and ventilation of the mine and how that would affect the presence of oxygen in the cave zone; this is considered a reasonable interpretation. However, the earlier interpretation—while not as advanced—is also a reasonable interpretation, and this source of uncertainty could result in higher concentrations that would cascade through the water quality modeling.

Uncertainty in effectiveness of engineered seepage controls

The effectiveness of engineered seepage controls is calculated differently for each alternative, using reasonable and valid modeling procedures. Only one of the alternatives (Alternative 4) represents solely a professional judgment (90% effectiveness) based on an understanding of hydrogeologic conditions and no other technical analysis.

The modeled effectiveness of engineered seepage controls is quite high for Alternative 2 (99 percent) and Alternative 3 (99.5 percent). These modeled estimates of effectiveness are not invalid and use reasonable techniques to estimate effectiveness. With respect to practicability, each individual type of engineered seepage control measure is based on standard industry practice, well-understood, and has been demonstrated in the field to be effective. However, it may be difficult in reality to meet the levels of effectiveness when all individual controls are layered together. This uncertainty, and the risk it holds to water quality impacts, represents a fundamental difference between alternatives and is discussed in detail for each alternative in section 3.7.2.4.

Commented [BM11]: This line should accompany the following section foot-acre estimates

Conclusion as to reasonableness of models

Given the relatively simple structure of the tailings storage facility water quality models and considering the effects of both modeling assumptions meant to intentionally bias towards worse effects, and uncertainties inherent in the techniques, the Forest Service concluded that:

- The models are based on valid and reasonable scientific methods and data.
- The models are considered reasonable to provide estimations for disclosure of possible impacts, provide a useful tool to gauge likely impacts relative to levels of required seepage control, and weigh the advantages and disadvantages between alternatives.

Forest Service disclosure and ADEQ permitting requirements

The State of Arizona has the sole authority to determine whether or not the proposed project would violate State water quality regulations. The person seeking authorization for a regulated discharge (in this case Resolution Copper) has the responsibility to demonstrate to the State of Arizona that the regulated discharge will not violate water quality standards. This demonstration takes place through the application for and issuance of permits. Resolution Copper will be required to obtain a permit under the Arizona Pollutant Discharge Elimination System (AZPDES) program for any discharges to surface waters, including stormwater runoff, as well as an aquifer protection permit (APP) for any discharges to groundwater, or discharges to the ground that could seep into groundwater.

The Forest Service is responsible for ensuring that mine operators on NFS lands obtain the proper permits and certifications to demonstrate they comply with applicable water quality standards. This constitutes compliance with the Clean Water Act. The record of decision will require that Resolution obtain the applicable state permits prior to approval of the final plan of operation, which authorizes mine activities.

If the permits are issued, then ADEQ has determined that the project would be compliant with state law and identified the steps that would occur if monitoring indicates noncompliance.

While the permitting process provides an assurance to the public that the project would not cause impacts to water quality, it does not relieve the Forest Service of several other responsibilities:

- The Forest Service has a responsibility to analyze and disclose to the public any potential impacts to surface water and groundwater as part of the NEPA process, separate from the state permitting process.
- The role of the Tonto National Forest under its primary authorities is to ensure that mining activities minimize adverse environmental effects on NFS lands and comply with all applicable laws and regulations. As such, the Forest Supervisor ultimately cannot select an alternative that is unable to meet applicable laws and regulations[3]. However, it may be after the EIS is published when permits are issued by ADEQ that demonstrate that the project complies with state laws. In the meantime, it would be undesirable for the Forest Service to pursue and analyze alternatives that may not be able to comply. Therefore, a second goal of the analysis in this EIS is to inform the Forest Supervisor of alternatives that may prove difficult to permit.

The analysis approaches used by the Forest Service in this EIS likely differ from those that will be used by ADEQ in assessing and issuing permits. ADEQ and would use the assumptions, techniques, tools, and data deemed appropriate for those permits. The Forest Service has selected to use a series of simpler mixing-cell models to provide a reasonable assessment of potential water quality impacts that is consistent with the level of hydrologic and geologic information currently available for the alternative tailings sites. This approach is sufficient to provide the necessary comparison between alternatives and assess the relative risk of violation of water quality standards. It is understood more sophisticated analysis may be conducted later when ADEQ is reviewing permit applications for the Preferred Alternative.

There are two specific additional aspects of the analysis in this section of the EIS that have a bearing on the ADEQ permitting process: impaired waters, and assimilative capacity.

ASSIMILATIVE CAPACITY

Assimilative capacity is the ability for a perennial water to receive additional pollutants without being degraded; assimilative capacity is calculated as the difference in concentration between the baseline water quality concentration for a pollutant and the most stringent applicable water quality criterion for that pollutant.

Under Arizona surface water regulations, the addition of a pollutant may be considered "significant degradation" of a perennial water if, during critical flow conditions, the regulated discharge consumes twenty percent or more of the available assimilative capacity for each pollutant of concern (Arizona Administrative Code R18-11-107.01(B)). The addition of contaminants to surface waters through seepage could result in a reduction in the assimilative capacity of perennial waters. The EIS contains an analysis of reductions in assimilative capacity.

The regulatory determination of significant degradation of perennial waters is solely under the purview of the State of Arizona. This determination is usually made when a permit is requested for a discharge

[3] Note that Alternative 6 would involve a tailings facility located off of federal lands and permitting the tailings facility would not be part of the federal decision. In this case, the state permitting process that would ensue would require that applicable laws and regulations be met.

directly to surface waters. However, Resolution Copper is not proposing any direct discharges to surface waters. Alternatively, ADEQ could consider the indirect effects of seepage from the tailings storage facility to surface waters under the aquifer protection permit program, or under a Clean Water Act Section 401 water quality certification (which is only done if a Clean Water Act Section 404 permit is required).

The twenty percent threshold that defines significant degradation is not absolute; if ADEQ decides to assess antidegradation standards as part of a permitting action, there are also provisions in Arizona regulations for degradation to be allowed, provided certain criteria are met (Arizona Administrative Code R18-11-107.C)

In other words, neither the regulatory need to assess assimilative capacity, nor the consequences of exceeding the twenty percent threshold can be assessed outside of a specific permitting decision by ADEQ. Regardless, the Forest Service responsibility for the DEIS is to disclose possible water quality concerns. This includes the reduction in assimilative capacity of a perennial water. For this purpose, a threshold of 20 percent loss in assimilative capacity is used[4].

IMPAIRED WATERS

Under the Clean Water Act, the State of Arizona must identify waters that are impaired for water quality[5]. As with assimilative capacity, the regulatory determination of how impaired waters could be affected by a discharge is solely under the purview of the State of Arizona.

For the purposes of disclosure, the Forest Service approach in the EIS is to identify what surface waters have been determined to be impaired, and where contaminants from the project could enter these surface waters and exacerbate an already impaired water.

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[4] The calculation of assimilative capacity depends in part the specific numeric surface water standard being used. Several surface water quality standards for metals change based on the hardness of the water. A hardness of 307 mg/L CaCO3 was used for Queen Creek, which is based on the lowest hardness observed (sample date August 25, 2017); a hardness of 290 mg/L CaCO3 was used for the Gila River below Donnelly Wash (sample date November 13, 2018); and a hardness of 242 mg/L CaCO3 was used for the Gila River below Dripping Springs Wash (sample date November 9, 2018). The addition of the modeled seepage does increase hardness but only slightly (less than 2%). The values of hardness used are based on the best available information at this time; ADEQ could choose to apply different hardness values during permitting. (continued)

The calculation of assimilative capacity also depends on specific "critical flow conditions" One technique (often called 7Q10) is to choose the lowest flow over seven consecutive days that has a probability of occurring once every 10 years. By contrast, the seepage modeling in the EIS uses the median flow for surface waters, which is a common method of estimating baseflow conditions, because it tends to exclude large flood events. While assessing typical baseflow conditions (using the median flow) were determined to be the most appropriate method for the EIS disclosure, ADEQ could choose to apply different flow conditions during permitting.

[5] "Impaired" refers to a regulatory designation under the Clean Water Act, and generally means that existing water quality is degraded to the point that an applicable water quality standard is not being attained.

Constituents of Concern

While the background references and reports contain information for the full suite of metals, inorganic constituents, and field measurements, the analysis we present in this section focuses on selected "constituents of concern". For example, Appendix K only includes graphs for the following constituents. These are constituents that are typically known to be issues for tailings facilities, or that the bypass seepage mixing/loading models have indicated may be a problem. These include:

- Total dissolved solids
- Sulfate
- Nitrate
- Selenium*, cadmium, antimony
- Copper
- Lead

Commented [BM12]: *Queen creek was identified as impaired for Se in 2012

Commented [BM13]: This is an EIS for a copper mine in an area with several copper impairments

Commented [BM14]: Queen creek was identified as impaired for Pb in 2010

3.7.2.3 Affected Environment

Relevant Laws, Regulations, Policies, and Plans

For the most part, impacts to groundwater and surface water quality fall under State of Arizona regulations, which are derived in part from the Clean Water Act. Additional details of the regulatory framework for groundwater and surface water quality are captured in the project record (Newell and Garrett 2018).

Primary Legal Authorities Relevant to the Groundwater and Surface Water Quality Analysis

- Clean Water Act
- State of Arizona Aquifer Water Quality Standards and the Aquifer Protection Permit Program
- State of Arizona Surface Water Quality Standards and the Arizona Pollutant Discharge Elimination System Program (delegated primacy for Clean Water Act Section 402)

Existing Conditions and Ongoing Trends

This section discusses three aspects of the affected environment:

- Existing groundwater quality for various aquifers, including what types and quantity of data have been collected to date; the general geochemistry of the groundwater for major constituents; the occurrence and concentrations of constituents of concern, compared with water quality standards; the age of the groundwater; and existing trends in groundwater quality.

- Existing surface water quality for various streams, including what types and quantity of data have been collected to date; the general geochemistry of surface waters for major constituents; and the occurrence and concentrations of constituents of concern, compared with water quality standards.
- Characterization of mine rock, including the types and quantity of data for different geological units that have been collected to date, and the static and kinetic laboratory testing undertaken to describe the likely changes in water quality when exposed to mine rock.

EXISTING GROUNDWATER QUALITY

Types of Groundwater Present

As more fully described in Section 3.7.1, Groundwater Quantity and Groundwater-Dependent Ecosystems, three types of groundwater exist in the area: shallow groundwater occurring in shallow alluvial materials, perched zones, or shallow fractures; the Apache Leap Tuff aquifer; and the deep groundwater system (units generally below the Whitetail Conglomerate, and extending into the Superior Basin) as seen in figure 3.7.1-X. These zones are identified as separate based on the different ages of the water within them and because they do not appear to be hydraulically connected based on aquifer testing.

Commented [CG15]: This will reference the stylized geologic cross-section being inserted into Section 3.7.1

The tailings facilities for Alternatives 2, 3, and 4 in the Superior Basin include shallow alluvial materials along washes and underlying fractured hard rock units like the Gila Conglomerate that are assumed to be in hydraulic connection with the deep groundwater system. The tailings facilities for Alternatives 5 and 6 are geographically separate from the Superior basin and overlie substantial alluvial aquifers associated with Donnelly Wash and Dripping Springs Wash, respectively, with some hard rock units along the margins of the facilities.

Period of Record for Groundwater Quality Data

Groundwater quality data have been collected since monitor well drilling and development was initiated in 2004, and collection continues into the present. Each monitoring well that is constructed is sampled for chemical analysis when completed, and then periodically resampled. Overall, 31 wells in the project area have been sampled since 2004, and a total of 150 samples has been collected to characterize groundwater in the project area through 2015. These samples are largely focused on the East Plant Site and surrounding areas.

Near the West Plant Site, 48 wells have been developed and sampled, from 2015–2017, yielding 102 samples of groundwater (including duplicate samples). This sampling has largely been the result of ongoing voluntary cleanup activities, and are generally geared towards assessing contamination rather than hydrogeologic conditions and general water quality.

Additional piezometers and monitoring wells were constructed in Near West area in 2016 and 2017, where the tailings storage facility for Alternatives 2 and 3 would be located. Groundwater quality results from these wells have not yet been submitted.

Several other sampling locations provide the basis for background water quality in the bypass seepage mixing/loading models. These include a well near Queen Creek (9 samples between 2017 and 2018), a well near Donnelly Wash (one sample in 2018), and a well near Dripping Springs Wash (one sample in 2018).

Types of Groundwater Quality Data Collected

All samples were analyzed for a wide range of chemical constituents, including water quality measurements made on water samples in the field at the point of collection (e.g., pH, temperature) and analyses conducted by Arizona-certified analytical laboratories. Some of the constituents analyzed are directly related to water quality, including those that have regulatory standards in the state of Arizona. Other constituents such as isotopes were sampled to help understand groundwater dynamics and the potential for interaction with local surface water resources [ADDIN EN.CITE <EndNote><Cite><Author>Garrett</Author><Year>2018</Year><RecNum>25251</RecNum><DisplayText>(Garrett 2018)</DisplayText><record><rec-number>25251</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546286091">25251</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Chris Garrett</author></authors></contributors><titles><title>Summary and Analysis of Groundwater-Dependant Ecosystems</title><secondary-title>Process memorandum to file</secondary-title></titles><dates><year>2018</year></dates><pub-location>Phoenix, Arizona</pub-location><publisher>SWCA Environmental Consultants. October 11</publisher><urls></urls><electronic-resource-num>110673</electronic-resource-num></record></Cite></EndNote>]. The number, date range, and types of samples collected are shown in table 3.7.2-2. A summary of existing groundwater quality for each aquifer is shown in Appendix J, Table J-1.

Table 3.7.2-2. Number of groundwater samples available for analysis

Type of Analysis	Shallow Groundwater Samples	Apache Leap Tuff Samples	Deep Groundwater Samples
General chemistry	25 (June 1986–Nov 2015)	104 (March 2004–Dec 2015)	19 (Nov 2008–Feb 2015)
Metals	25 (June 1986–Nov 2015)	105 (March 2004–Dec 2015)	19 (Nov 2008–Feb 2015)

Isotopes	24 (June 1986–May 2012)	90 (March 2004–Dec 2015)	19 (Nov 2008–Feb 2015)
Radionuclides	12 (June 2007–Dec 2008)	63 (June 2007–Dec 2015)	19 (Nov 2008–Feb 2015)

Chemical Quality of Groundwater

There are differences in water quality among the three principal groundwater sources (shallow, Apache Leap Tuff, deep groundwater system) in the project area [ADDIN EN.CITE <EndNote><Cite><Author>Montgomery and Associates Inc.</Author><Year>2012</Year><RecNum>25274</RecNum><DisplayText>(Montgomery and Associates Inc. 2012, 2016)</DisplayText><record><rec-number>25274</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546368792">25274</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Montgomery and Associates Inc.,</author></authors></contributors><titles><title>Results of Hydrochemical Characterization of Groundwater Upper Queen Creek/Devils Canyon Study Area: Resolution Copper Mining LLC, Pinal County, AZ</title><secondary-title>Prepared for Resolution Copper</secondary-title></titles><dates><year>2012</year></dates><pub-location>Tucson, Arizona</pub-location><publisher>Montgomery and Associates Inc. March 15</publisher><urls></urls><electronic-resource-num>43</electronic-resource-num></record></Cite><Cite><Author>Montgomery and Associates Inc.</Author><Year>2016</Year><RecNum>25275</RecNum><record><rec-number>25275</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546369043">25275</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Montgomery and Associates Inc.,</author></authors></contributors><titles><title>Hydrochemistry Addendum Groundwater and Surface Water, Upper Queen Creek/Devils Canyon Study Area</title><secondary-title>Prepared for Resolution Copper</secondary-title></titles><dates><year>2016</year></dates><pub-location>Tucson, Arizona</pub-location><publisher>Montgomery and Associates Inc. August 11</publisher><urls></urls><electronic-resource-num>1002</electronic-resource-num></record></Cite></EndNote>][6]. The shallow groundwater system can be described as a calcium/magnesium bicarbonate type with varying amounts of sulfate. The total dissolved solids content is generally low (median of 290 milligrams per liter (mg/L)). Constituents in water samples from the shallow groundwater system rarely have concentrations above Arizona numeric Aquifer Water Quality Standards (AWQS) and EPA primary maximum contaminant levels, with nitrate and lead being the only constituents with concentrations above these standards. Samples also rarely have concentrations above EPA secondary maximum contaminant levels, but this does occur for iron, manganese, sulfate, aluminum, and total dissolved solids; secondary standards are generally established for aesthetics and taste, rather than safety.

The Apache Leap Tuff aquifer has been sampled much more than either the shallow or deep systems, since it is the aquifer from which most springs and stream derive their flow. Overall the Apache Leap Tuff is a calcium-magnesium-bicarbonate water type, with low total dissolved solids (median of 217 mg/L). Constituents in water samples from the Apache Leap Tuff rarely appear in concentrations above Arizona numeric AWQS or EPA primary standards, although this has occurred for antimony, thallium, and beryllium. Concentrations above EPA secondary standards occur occasionally for aluminum, iron, and manganese, and rarely for total dissolved solids.

[6] For a complete summary of the number of samples with concentrations over Arizona or EPA standards to support the qualitative terms used in this section (i.e., "rarely", "occasionally", "often"), see Newell and Garrett 2018.

The overall water quality of the deep groundwater system is more variable than the shallow and Apache Leap Tuff systems, with greater total dissolved solids (median of 410 mg/L) that often can be above the EPA secondary standard. Only one sample (in 2011) exhibited concentrations above AWQS values. Concentrations often are above EPA secondary standards for aluminum, iron, manganese, sulfate, and fluoride. Samples with elevated sulfate, total dissolved solids, iron, and manganese appear to be within the proposed mineralized ore zone [ADDIN EN.CITE <EndNote><Cite><Author>Montgomery and Associates Inc.</Author><Year>2012</Year><RecNum>25274</RecNum><DisplayText>(Montgomery and Associates Inc. 2012)</DisplayText><record><rec-number>25274</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546368792">25274</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Montgomery and Associates Inc.,</author></authors></contributors><titles><title>Results of Hydrochemical Characterization of Groundwater Upper Queen Creek/Devils Canyon Study Area: Resolution Copper Mining LLC, Pinal County, AZ</title><secondary-title>Prepared for Resolution Copper</secondary-title></titles><dates><year>2012</year></dates><pub-location>Tucson, Arizona</pub-location><publisher>Montgomery and Associates Inc. March 15</publisher><urls></urls><electronic-resource-num>43</electronic-resource-num></record></Cite></EndNote>].

Groundwater is also extracted from Shaft No. 9 as part of the ongoing dewatering. Groundwater associated with discharge from Shaft No. 9 has very high sulfate concentrations and, by extension, elevated total dissolved solids. Numerous constituents can be found in concentrations above Arizona numeric AWQS and EPA primary and secondary standards. This sampling location should not, however, be considered representative of the deep groundwater system as it has been affected by mine activity. The impacts at this location appear to be influenced by sulfide mineral oxidation, although the solution is routinely near neutral pH.

Age of Groundwater

Chemical characteristics of groundwater (isotopes) that may be used to assess age do not have explicit regulatory standards. Carbon-14 (^{14}C) and tritium have both been measured in shallow system, Apache Leap Tuff aquifer, and deep groundwater system to constrain age and provide understanding of water movement. These isotopic measurements indicate that shallow groundwater is typically estimated to be less than 700 years old, whereas Apache Leap Tuff and deep groundwater are 3,000–5,000 and 6,000–15,000 years old, respectively.

Trends in Groundwater Quality

Based on groundwater samples collected roughly between 2003 and 2015, over time the groundwater quality, in terms of major chemical constituents (e.g., calcium, magnesium, bicarbonate, sulfate) has remained generally stable in the shallow groundwater system and Apache Leap Tuff aquifer. The shallow system has displayed the greatest amount of variation, largely confined to variations in sulfate concentration. Although data for deep groundwater show significant variation with location, available data indicate there is little seasonal variability.

EXISTING SURFACE WATER QUALITY

Surface water occurs broadly across the entire project area. The settings in which surface water occurs span a wide range, from small to large drainage areas and channels and with highly variable flow rates. The kinds of surface water present (including springs and perennial streams) are described in further detail in both the "Groundwater Quantity and Groundwater-Dependent Ecosystems" and "Surface Water Quantity" sections in this chapter.

Period of Record for Surface Water Quality Data

The surface water baseline monitoring program for the project area was initiated in 2003 and has continued through present, with a 2-year hiatus in 2006 and 2007. Although surface water data have been collected since 2003, the number of samples collected varies from location to location and no locations have been sampled every year. Water quality data are available for a total of 47 locations. Through 2015, 505 samples of surface water have been collected and chemically analyzed for 37 water quality parameters.

Most surface water monitoring has been conducted in the Devil's Canyon watershed (main canyon and two tributaries). Queen Creek, along the northern margin of Oak Flat prior to entering the Superior area, has also been extensively characterized [ADDIN EN.CITE <EndNote><Cite><Author>Montgomery and Associates Inc.</Author><Year>2013</Year><RecNum>25276</RecNum><DisplayText>(Montgomery and Associates Inc. 2013, 2017)</DisplayText><record><rec-number>25276</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546369343">25276</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Montgomery and Associates Inc.,</author></authors></contributors><titles><title>Surface Water Baseline Report: Devils Canyon, Mineral Creek and Queen Creek Watersheds, Resolution Copper Mining LLC, Pinal County, Arizona</title><secondary-title>Prepared for Resolution Copper</secondary-title></titles><dates><year>2013</year></dates><pub-location>Tucson, Arizona</pub-location><publisher>Montgomery and Associates Inc. May 16</publisher><urls></urls><electronic-resource-num>45</electronic-resource-num></record></Cite><Cite><Author>Montgomery and Associates Inc.</Author><Year>2017</Year><RecNum>25277</RecNum><record><rec-number>25277</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546369590">25277</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Montgomery and Associates Inc.,</author></authors></contributors><titles><title>Surface Water Baseline Addendum: Upper Queen Creek, Devils Canyon, and Mineral Creek Watersheds</title><secondary-title>Prepared for Resolution Copper</secondary-title></titles><dates><year>2017</year></dates><pub-location>Tucson, Arizona</pub-location><publisher>Montgomery and Associates Inc. January 26</publisher><urls></urls><electronic-resource-num>1272</electronic-resource-num></record></Cite></EndNote>].

Several other sampling locations provide the basis for background water quality in the bypass seepage mixing/loading models. These include a Queen Creek at Whitlow Ranch Dam (15 samples between 2017 and 2018), the Gila River below Donnelly Wash (one sample in 2018), and the Gila River below Dripping Springs Wash (one sample in 2018).

Types of Surface Water Quality Data Collected

As with groundwater, all samples were analyzed for a wide range of chemical constituents, including water quality measurements made on water samples in the field at the point of collection (e.g., pH, temperature) and analyses conducted by Arizona-certified analytical laboratories. Some of the constituents analyzed are directly related to water quality, including those that have regulatory standards in the state of Arizona. Other constituents such as isotopes were sampled to help understand groundwater dynamics and the potential for interaction with local surface water resources (see Garrett 2018).

Chemical Quality of Surface Waters

In general, surface water in the area is a calcium-sodium-bicarbonate type, with a neutral to alkaline pH. The major element composition of surface water does not vary widely across the project site and does not show any identifiable long-term trends, either increasing or decreasing. However, in Devil's Canyon and Queen Creek, statistically significant short-term seasonal trends have been identified for copper (Devil's

Canyon) and sulfate (Devil's Canyon and Queen Creek). These seasonal trends appear to be linked with increased precipitation, with higher concentrations observed during periods of increased runoff in the winter rainy season and summer monsoons. The increases are likely due to washing of evaporative salts that may form during drier times of the year. It also may not, as discussed in previous reviews this has not been demonstrated at this location. Given the importance of that assumption to the understanding of these systems it is inappropriate to make that assertion lacking supporting evidence

During drier periods, some surface water appears to be supported more by groundwater discharge and is more chemically stable. No consistent temporal trends were identified for chloride, sodium, potassium, calcium, or magnesium anywhere in the project area. Appendix J, table J-2 presents a summary of water quality for defined reaches of the principal drainages, for filtered water samples. Appendix J, table J-3 presents the same types of data for unfiltered samples.

Commented [BM16]: Based on what data or study? TMDL study data suggests there is a seasonality to storm flows that would include these constituents, especially CA

For the three principal drainages associated with the project—Devil's Canyon, Queen Creek, and Mineral Creek—water quality is impacted by historic and present mining ~~generally considered to be of acceptable quality, although~~, all three have exhibited concentrations above Arizona surface water quality standards at different times for copper. ~~several different constituents~~ [ADDIN EN.CITE <EndNote><Cite><Author>Montgomery and Associates Inc.</Author><Year>2017</Year><RecNum>25277</RecNum><DisplayText>(Montgomery and Associates Inc. 2013, 2017)</DisplayText><record><rec-number>25277</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546369590">25277</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Montgomery and Associates Inc.,</author></authors></contributors><titles><title>Surface Water Baseline Addendum: Upper Queen Creek, Devils Canyon, and Mineral Creek Watersheds</title><secondary-title>Prepared for Resolution Copper</secondary-title></titles><dates><year>2017</year></dates><pub-location>Tucson, Arizona</pub-location><publisher>Montgomery and Associates Inc. January 26</publisher><urls></urls><electronic-resource-num>1272</electronic-resource-num></record></Cite><Cite><Author>Montgomery and Associates Inc.</Author><Year>2013</Year><RecNum>25276</RecNum><record><rec-number>25276</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546369343">25276</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Montgomery and Associates Inc.,</author></authors></contributors><titles><title>Surface Water Baseline Report: Devils Canyon, Mineral Creek and Queen Creek Watersheds, Resolution Copper Mining LLC, Pinal County, Arizona</title><secondary-title>Prepared for Resolution Copper</secondary-title></titles><dates><year>2013</year></dates><pub-location>Tucson, Arizona</pub-location><publisher>Montgomery and Associates Inc. May 16</publisher><urls></urls><electronic-resource-num>45</electronic-resource-num></record></Cite></EndNote>]. Most notably, Queen Creek, from the headwaters of Potts Canyon, is listed by the ADEQ as impaired for copper. Overall, dissolved copper concentrations were significantly higher at sites in the Queen Creek watershed than in the Devil's Canyon and Mineral Creek watersheds; dissolved copper concentrations in the Devil's Canyon watershed generally decreased with distance downstream and were significantly higher than in the Mineral Creek watershed.

Commented [BM17]: Copper, selenium, DO, lead are all impairments on these waterbodies. The phrase "generally considered to be of acceptable quality" is incorrect here.

Commented [BM18]: This does not bear out, can provide additional information as needed

A summary of the number of surface water samples with concentrations above Arizona numeric surface water standards is included in Appendix J, table J-4. A summary of Arizona numeric surface water standards and which bodies they are applicable to is included in Appendix J, table J-5.

Commented [BM19]: Matt needs to review for accuracy

MINE ROCK ANALYSIS

Rock within the proposed subsurface zone of mining is highly mineralized. However, not all the rock that is mineralized is ore grade and identified for proposed recovery. Much mineralized rock will remain in place during, and after mining. This rock contains sulfide minerals (e.g., pyrite, iron disulfide) and other metal-containing material. During mining, and after mining for some time, exposure of these minerals to oxygen could lead to their chemical weathering. This weathering may contribute acidity and metals to contact water and diminish its overall quality. The mine rock has been sampled and analyzed to assess the extent to which it might affect water that accumulates and is removed during mining, as well as the potential effects on groundwater that floods the mine void after mining is completed.

Amount of Geochemistry Tests Conducted

Various rock units make up mine rock. Over geological time, temperatures in the earth alter the original rock type, which modifies its original mineralogy to some degree. Overall, the combination of rock units and types forms the range of materials that occurs in the mineralized zone.

MWH Americas [ADDIN EN.CITE <EndNote><Cite ExcludeAuth="1"><Author>MWH Americas Inc.</Author><Year>2013</Year><RecNum>24934</RecNum><DisplayText>(2013)</DisplayText><record><rec-number>24934</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1536269639">24934</key></foreign-keys><ref-type name="Book Section">5</ref-type><contributors><authors><author>MWH Americas Inc.,</author></authors></contributors><titles><title>Appendix G: Geochemical Characterization Data Summary Report</title><secondary-title>General Plan of Operations, Resolution Copper Mining</secondary-title></titles><dates><year>2013</year></dates><pub-location>Fort Collins, Colorado</pub-location><publisher>MWH Americas Inc. August</publisher><urls></urls><electronic-resource-num>54</electronic-resource-num></record></Cite></EndNote>] reports the rock units and alteration types that have been evaluated, and the number of samples for each. This information is summarized in table 3.7.2-3. Overall, 226 samples were submitted for analysis of Tier 1 procedures, with 13 duplicates for a total of 239 samples. Following completion of Tier 1 testing, 15 samples were identified and submitted for Tier 2 evaluation. Specific Tier 1 and Tier 2 tests are described in the next section

Table 3.7.2-3. Rock units, alteration types, and number of samples submitted for geochemical evaluation

Code	Rock Unit	Count
Tal	Tertiary Apache Leap Tuff (Ignimbrite)	7
Tw	Tertiary Whitetail Conglomerate	11
Kvs	Cretaceous volcanics and sediments (undifferentiated)	101
Kqs	Cretaceous quartz-rich sediments	1
QEP	Quartz eye porphyry; rhyodacite porphyry	37
FP/LP	Felsic porphyry; latite porphyry	3
Dm	Devonian Martin limestone (skarn)	21
Andesite	Andesite	1
Diabase	Diabase	22
Qzite	Quartzite	17
Breccia/Hbx	Heterolithic breccia	3
Fault	Fault	2

	Total	**226**
	Alteration Type	
Code	**Rock Unit**	**Count**
AA	Advanced argillic	19
ARG	Argillic	1
HFLRET	Retrograde hornfels	5
PHY	Phyllic	111
POT	Potassic	31
PRO	Propylitic	16
SA	Supergene argillic	7
SIL	Siliceous	1
SKN/SKRET	Skarn/Retrograde skarn	16
UNALT	Unaltered	18
ZEO	Zeolite	1
	Total	**226**

Types of Geochemistry Tests Conducted

Mine rock has been evaluated using a range of established, standard (best practices) methods for the mining industry [ADDIN EN.CITE <EndNote><Cite><Author>International Network for Acid Prevention</Author><Year>2018</Year><RecNum>25278</RecNum><DisplayText>(International Network for Acid Prevention 2018)</DisplayText><record><rec-number>25278</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546370920">25278</key></foreign-keys><ref-type name="Web Page">12</ref-type><contributors><authors><author>International Network for Acid Prevention,</author></authors></contributors><titles><title>Global Acid Rock Drainage Guide (GARD Guide)</title></titles><number>January 1, 2019</number><dates><year>2018</year></dates><urls><related-urls><url>http://www.gardguide.com/index.php?title=Main_Page</url></related-urls></urls><electronic-resource-num>110894</electronic-resource-num></record></Cite></EndNote>] as well as those that are regulatorily mandated procedures [ADDIN EN.CITE <EndNote><Cite><Author>Arizona Department of Environmental Quality</Author><Year>2004</Year><RecNum>23432</RecNum><DisplayText>(Arizona Department of Environmental Quality 2004)</DisplayText><record><rec-number>23432</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="0">23432</key></foreign-keys><ref-type name="Book">6</ref-type><contributors><authors><author>Arizona Department of Environmental Quality,</author></authors></contributors><titles><title>Arizona Mining Guidance Manual BADCT</title><secondary-title>Aquifer Protection Program. Publication No. TB-04-01</secondary-title></titles><dates><year>2004</year></dates><pub-location>Phoenix, Arizona</pub-location><publisher>Arizona Department of Environmental Quality</publisher><urls></urls><electronic-resource-num>709</electronic-resource-num></record></Cite></EndNote>]. These methods assess:

- the potential for rock to generate acidic drainage,
- the rate at which such acid generation may occur, and

- what constituents of concern might be released and their associated concentrations.

Specific methods include:

- whole rock chemical composition (concentration of wide range of elements),
- acid-base accounting [ADDIN EN.CITE <EndNote><Cite><Author>Sobek</Author><Year>1978</Year><RecNum>25279</RecNum><DisplayText>(Sobek et al. 1978)</DisplayText><record><rec-number>25279</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546371328">25279</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Andrew Sobek</author><author>William A. Schuller</author><author>John R. Freeman</author><author>Richard M. Smith</author></authors></contributors><titles><title>Field and Laboratory Methods Applicable to Overburden and Mine Soils</title><secondary-title>EPA-600/2-78-054</secondary-title></titles><dates><year>1978</year></dates><pub-location>Cincinnati, Ohio</pub-location><publisher>Industrial Environmental Research Laboratory, Office of Research and Development, U.S. Enviromental Protection Agency. March</publisher><urls></urls><electronic-resource-num>959</electronic-resource-num></record></Cite></EndNote>],
- net acid generation test [ADDIN EN.CITE <EndNote><Cite><Author>Stewart</Author><Year>2006</Year><RecNum>25280</RecNum><DisplayText>(Stewart et al. 2006)</DisplayText><record><rec-number>25280</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546371660">25280</key></foreign-keys><ref-type name="Conference Paper">47</ref-type><contributors><authors><author>Warwick A. Stewart</author><author>Stuart D. Miller</author><author>Roger Smart</author></authors></contributors><titles><title>Advances in acid rock drainage (ARD) characterisation of mine wastes</title><secondary-title>7th International Conference on Acid Rock Drainage (ICARD)</secondary-title></titles><dates><year>2006</year><pub-dates><date>March 26-30</date></pub-dates></dates><pub-location>St. Louis, Missouri</pub-location><publisher>American Society of Mining and Reclamation</publisher><urls></urls><electronic-resource-num>769</electronic-resource-num></record></Cite></EndNote>],
- synthetic precipitation leaching procedure [ADDIN EN.CITE <EndNote><Cite><Author>U.S. Environmental Protection Agency</Author><Year>1994</Year><RecNum>25282</RecNum><DisplayText>(U.S. Environmental Protection Agency 1994)</DisplayText><record><rec-number>25282</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546372734">25282</key></foreign-keys><ref-type name="Web Page">12</ref-type><contributors><authors><author>U.S. Environmental Protection Agency.</author></authors></contributors><titles><title>Method 1312: Synthetic Precipitation Leaching Procedure</title></titles><number>January 1, 2019</number><dates><year>1994</year></dates><urls><related-urls><url>https://www.epa.gov/sites/production/files/2015-12/documents/1312.pdf</url></related-urls></urls><electronic-resource-num>110895</electronic-resource-num></record></Cite></EndNote>],
- humidity cell testing [ADDIN EN.CITE <EndNote><Cite><Author>American Society for Testing and Materials</Author><Year>1996</Year><RecNum>25281</RecNum><DisplayText>(Ameri

can Society for Testing and Materials 1996)</DisplayText><record><rec-number>25281</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546372264">25281</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>American Society for Testing and Materials.</author></authors></contributors><titles><title>Standard Test Method for Accelerated Weathering of Solid Materials Using a Modified Humidity Cell</title><secondary-title>Designation: D 5744 – 96 (Reapproved 2001)</secondary-title></titles><dates><year>1996</year></dates><pub-location>West Conshohocken, Pennsylvania</pub-location><publisher>ASTM International</publisher><urls></urls><electronic-resource-num>949</electronic-resource-num></record></Cite></EndNote>], and

- saturated column testing (a project-specific test to leach the residual humidity cell testing procedure material).

The first four procedures (whole rock chemical composition, acid-base accounting, net acid generation test, and synthetic precipitation leaching procedure) are Tier 1 procedures required in the Arizona Best Available Demonstrated Control Technology (BADCT) guidance [ADDIN EN.CITE <EndNote><Cite><Author>Arizona Department of Environmental Quality</Author><Year>2004</Year><RecNum>23432</RecNum><DisplayText>(Arizona Department of Environmental Quality 2004)</DisplayText><record><rec-number>23432</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="0">23432</key></foreign-keys><ref-type name="Book">6</ref-type><contributors><authors><author>Arizona Department of Environmental Quality.</author></authors></contributors><titles><title>Arizona Mining Guidance Manual BADCT</title><secondary-title>Aquifer Protection Program. Publication No. TB-04-01</secondary-title></titles><dates><year>2004</year></dates><pub-location>Phoenix, Arizona</pub-location><publisher>Arizona Department of Environmental Quality</publisher><urls></urls><electronic-resource-num>709</electronic-resource-num></record></Cite></EndNote>]. The last two are called for in the Tier 2 test level requirements, which are generally conducted on fewer samples but take place over a longer period of time.

Beyond these chemical testing methods that directly assess potential impacts on the quality of contacting water, mine rock has been evaluated using mineralogical techniques such as:

- petrography (microscopic evaluation of mineral grain sizes and contact boundaries),
- x-ray diffraction (identifies actual minerals present and their abundance), and
- scanning electron microscopy (evaluation of mineral textures).

Geochemical testing fundamentally is meant to determine if a given rock sample is potentially acid generating or not, and if so, to what extent. The geochemical tests indicate that there are numerous rock units associated with the project that have acid generation potential; geochemical tests on simulated tailings samples similarly have demonstrated the potential for acid generation.

3.7.2.4 Environmental Consequences of Implementation of the Proposed Mine Plan and Alternatives

No Action Alternative

Under the no action alternative, seepage would not develop from a tailings facility and contribute to chemical loading in downgradient aquifers or surface waters, and stormwater would not potentially contact tailings, ore, or process areas. Water quality in the block-cave zone and surrounding aquifers would continue to match current conditions.

Impacts Common to All Action Alternatives

EFFECTS OF THE LAND EXCHANGE

[Note to reviewers: This section is being added consistently to all resource sections in response to comments on review of the administrative draft EIS]

FOREST PLAN AMENDMENT

[Note to reviewers: This section is being added consistently to all resource sections in response to comments on review of the administrative draft EIS]

SUMMARY OF APPLICANT-COMMITTED ENVIRONMENTAL PROTECTION MEASURES

A number of environmental protection measures are incorporated into the design of the project that would act to reduce potential impacts to groundwater and surface water quality. These are non-discretionary measures and their effects are accounted for in the analysis of environmental consequences.

- Stormwater controls (described in detail in "Potential Surface Water Quality Impacts from Stormwater Runoff")
- Engineered seepage controls (described in detail in "Potential Groundwater Quality Impacts from Tailings Seepage")

POTENTIAL GROUNDWATER QUALITY IMPACTS WITHIN BLOCK-CAVE ZONE

Potential for Subsidence Lake Development

Three simultaneous events will take place that suggest there could be the potential for the creation of a surface lake on Oak Flat after closure of the mine:

- The subsidence crater will develop. The base case model run indicates the crater would be about 800 feet deep. Most of the sensitivity runs of the subsidence model are similar, although one sensitivity model run reached about 1,100 feet deep [ADDIN EN.CITE <EndNote><Cite><Author>Itasca Consulting Group</Author><Year>2018</Year><RecNum>25220</RecNum><DisplayText>(Itasca Consulting Group 2018)</DisplayText><record><rec-number>25220</rec-number><foreign-keys><key app="EN" db-id="rx9ap0wwhzsrxkevts2595ekpdpst9zfz9d5" timestamp="1546116316">25220</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Itasca Consulting Group,</author></authors></contributors><titles><title>Subsidence Impact Analysis - Sensitivity Study: Addendum to Itasca Report "Assessment of Surface Subsidence Associated with Caving - Resolution Copper Mine Plan of

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Operations"</title><secondary-title>Prepared for Resolution Copper Company</secondary-title></titles><dates><year>2018</year></dates><pub-location>Minneapolis, Minnesota</pub-location><publisher>Itasca Consulting Group. April 6</publisher><urls></urls><electronic-resource-num>2423</electronic-resource-num></record></Cite></EndNote>].

Commented [BM20]: If the crater fills completely, the resultant lake will be the deepest freshwater body in Arizona, and the 4th deepest lake in the western continental United States. If dry, this would be deeper than the Hoover dam is tall

- Groundwater levels will rebound and rise as the aquifer equilibrates after dewatering is curtailed after closure of the mine.
- Block-caving will have created a hydraulic connection from the surface to the deep groundwater system and eliminated any intervening layers like the Whitetail Conglomerate that formerly were able to prevent or slow vertical groundwater flow.

The Groundwater Modeling Workgroup explored the potential for a subsidence lake to form. Ultimately the Forest Service determined that the presence of a subsidence lake was speculative and not reasonably foreseeable, and as such it would therefore be inappropriate to analyze in the EIS. The uncertainties are such that it would not be possible to adequately analyze a subsidence lake, even if it were appropriate to do so. The Forest Service determined this based on the following rationale:

Commented [BM21]: Who was in this workgroup?

Commented [BM22]: Given the potential and severity of the impacts described here, and the likelihood that a crater/crater lake would greatly impact the water environment and quality, and the environment of Eastern AZ: Region 9 EPA respectfully disagrees with our colleagues in The Groundwater Modeling Workgroup on their findings that it is inappropriate to analyze the crater and the possible lake in the EIS. While traditional modeling may not be a readily available option, there are several avenues to fully analyze the whole range of potential outcomes and impacts. The enormity of these impacts require that they be reviewed in whole.

- For a subsidence lake to from, groundwater levels would have to rebound to an elevation greater than the bottom of the subsidence crater. Resolution Copper modeled this process as taking about 980 years, or possibly as early as 500 years based on some of the sensitivity analyses. The Groundwater Modeling Workgroup identified 200 years as being the limit of reliability for quantitative predictions obtained from the groundwater flow model.
- The presence of a subsidence lake depends heavily on the absolute elevation of the bottom of the crater. While there is little doubt that a subsidence crater would develop, modeling the magnitude of subsidence carries substantial uncertainty, and the exact elevation of the bottom of the subsidence crater relies on accurate predictions of subsidence magnitude.
- The presence of a subsidence lake depends also on the absolute elevation of the water table as it rebounds. While there is also little doubt that groundwater levels would rebound after cessation of dewatering, the absolute elevation of model results is one of the most uncertain aspects of modeled predictions. It is for this reason that drawdown, not absolute elevation, was used in prediction of impacts to GDEs; drawdown relies on a comparison of starting water levels with future water levels, and if there are errors in calibration at a specific location, using drawdown effectively negates these errors. Absolute elevation, on the other hand, would incorporate any calibration errors. The model as a whole is well calibrated, but individual spot locations could show calibration errors of dozens of feet, in places over 100 feet.

Commented [BM23]: Is this defined elsewhere?

While the fundamental processes needed to create a subsidence lake are reasonably foreseeable—rebounding water levels, subsiding ground surface, fracturing of intervening geologic layers—the long time frames involved, compounded by the uncertainty of both the subsidence and groundwater models, provides no reasonable basis to predict that these processes will come together in a way that will actually create a lake within the subsidence crater.

Similarly, if a lake developed, it is not possible to predict the details that would be necessary to conduct even a rudimentary analysis of effects. For instance, the depth of the lake cannot be known with any accuracy. However, that single parameter would affect both the amount of inflow of native groundwater and the amount of evaporation that would occur from the lake surface, and it is the interplay of these two parameters that largely determines how constituents would concentrate in the lake and whether the ultimate water quality would be hazardous to wildlife.

Commented [BM24]: Based on this conclusion, all foreseeable permutations should be modeled given the size and potential magnitude of the impacts to western Arizona.

Ultimately, the Forest Service determined that a lake in theory may form in the subsidence crater 500 or more years following mine closure, but it is not possible to predict whether or not such a lake will actually occur, or the size or depth of such a lake should it occur.

Commented [BM25]: Should the crater form, but remain dry how would this new topography impact local surface waters directly through changes in shallow subsurface flow? How would this direct connection to groundwater impact volumes of

Potential for Other Exposure Pathways for Block-Cave Groundwater

The Groundwater Modeling Workgroup explored the potential for exposure to block-cave groundwater at the surface other than through a subsidence lake. The Magma Mine workings connect the block-cave area to the ground surface, and questions arose if the historic workings of the Magma Mine could be a pathway for block-cave groundwater to emerge at the surface.

Ultimately the group determined that block-cave groundwater would not rise to an elevation that would allow it to daylight through the Magma Workings, and thus there would be little potential for exposure to block-cave groundwater. The Groundwater Modeling Workgroup determined this based on the following rationale:

- During operations, pumping would dewater the Magma Mine workings. After dewatering ends, groundwater collected water in the Magma Mine workings would drain towards the block-cave zone, and not outwards.
- The Magma mine portal that comes to surface at the lowest elevation (MSD One Portal) daylights at an elevation of 2,930 ft amsl. This is higher than the bottom of the subsidence crater. As described above in the section about a potential subsidence lake, it would take centuries for the groundwater to rebound to the elevation of the subsidence crater bottom at an elevation of approximately 2,800 ft amsl, and thus even longer for it to reach an elevation where groundwater from the block-cave zone would drain towards the MSD One Portal.
- A tunnel that drains away from the block-cave zone (Never Sweat Tunnel) intercepts the subsidence crater at approximately 3,200 feet amsl. Groundwater would not rise to the elevation of the Never Sweat Tunnel in the reasonably foreseeable future, if ever.
- The cone of depression in the aquifer created by the mine dewatering would persist for hundreds of years, creating hydraulic conditions that preventing subsurface flow away from the block-cave area.

Commented [BM26]: Is it common for these reports to discount future impacts?

Predicted Block-Cave Water Quality at Closure

The water quality in the block-cave sump at the end of active mining was modeled using the block-cave geochemistry model (Eary 2018f), as shown previously in table 3.7.2-1. At the end of mine life, no constituents in the block-cave sump are anticipated to have concentrations above Arizona numeric AQWS except for thallium. Several constituents are anticipated to have concentrations above EPA secondary standards, including aluminum, fluoride, sulfate, and total dissolved solids, and arsenic is anticipated to be above the EPA primary standard (which is lower than the Arizona numeric AQWS).

Post-Closure Trends in Block-Cave Water Quality

Even if ventilation assumptions used in Eary (2018f) bear out during operations, weathering products may accumulate on collapsed, mineralized, rock in the block cave during mining due to the exposure to humid air and oxygen. If the oxygenated conditions of Hatch ([redacted]) dominate, some of these products will dissolve in downward migrating Apache Leap Tuff groundwater. Some can, however, be expected to be retained on unrinsed rock. These products will be dissolved in water that floods the block cave post-mining. Because these products are not associated with the block cave water quality model, their release to reflooding waters will increase the concentration of chemical constituents and the water quality would worsen over time, potentially resulting in concentrations of metals (antimony, beryllium, cadmium, chromium, lead, nickel, selenium, thallium) above Arizona aquifer water quality standards, as shown in table 3.7.2-1.

POTENTIAL SURFACE WATER QUALITY IMPACTS FROM STORMWATER RUNOFF

Stormwater Controls and Potential for Discharge of Stormwater

Construction and Operation Phases

Stormwater control measures for each alternative are described in Newell and Garrett (2018). During construction, temporary sediment and erosion controls would be implemented as required under a stormwater permit issued by ADEQ. These controls would include physical control structures as well as best management practices. Physical control structures could include diversions, berms, sediment traps, detention basins, silt fences or straw wattles. Best management practices could include limiting vegetation removal, good housekeeping, proper material storage, and limiting ground disturbance. Stormwater control measures are generally kept in place until disturbed areas are stabilized either through revegetation or by permanent constructed facilities.

Generally speaking, during operations any precipitation or runoff that comes into contact with tailings, ore, hazardous material storage areas, or processing areas is considered "contact water". During operations contact water would be captured, contained in basins, pumped out after storm events, and recycled back into the process water stream. This type of containment would be required by both the stormwater and aquifer protection permits that would be issued for the project. Contact water would not be released to the environment at any time during operations.

There are areas of the West Plant Site and Filter Plant/Loadout Facility that are undisturbed or contain only ancillary facilities. Stormwater from these areas is considered "non-contact" stormwater. In many cases, upstream runoff will be diverted around the project facilities to prevent the stormwater from becoming contact water and allowed to continue flowing into downstream drainages. Non-contact stormwater is allowed to leave the property.

Commented [BM27]: How will this be managed to prevent WQS impacts that come with normal stormwater issues? Using the BMPs that are mentioned above?

The tailings storage facility generally follows the same strategy during operations. For all alternatives, runoff from upstream of the facility is diverted around the facility to prevent any contact with tailings. For the Alternatives 2, 3, 5, and 6, any precipitation falling within the facility would run into the recycled water pond, and any runoff from the external embankments would be routed to the downstream seepage collection ponds, then pumped back and recycled into the process water stream. For the Alternative 4, with filtered tailings, the tailings surface is designed to minimize ponding, and all contact water is routed to downstream seepage collection ponds. As with the other alternatives, the water from the Alternative 4 seepage collection ponds would be pumped back and recycled in the process water stream; however, with Alternative 4 the water quality running off of the PAG tailings facility may be such that it requires further treatment prior to reuse.

Closure and Post-Closure Phases

With respect to stormwater, the goal upon closure is to stabilize disturbed areas, minimize long-term active management, and return as much flow as possible to the environment. This is readily accomplished at the East Plant Site, West Plant Site, and Filter Plant/Loadout Facility once facilities are demolished and removed, and the sites are revegetated. Closure details for these areas are included in Sections 6.5, 6.6, 6.8, and Appendix Y of the GPO (Resolution Copper 2016).

The tailings storage facility represents a more complex closure problem, regardless of alternative. The specific goals of closing the tailings storage facility are:

- Develop a stable landform
- Develop a stable vegetated cover that limits infiltration and protects surface water quality by preventing contact of stormwater with tailings
- Minimize ponded water on the closed tailings surface
- Limit access of oxygen to PAG tailings to prevent oxidation of pyrite materials (acid rock drainage)
- Protect the reclaimed surface against wind or water erosion
- Provide a growth medium for vegetation to establish and be sustained in perpetuity

Closure of the tailings facilities for Alternatives 2, 3, 5, and 6 is a long-term phased process that involves gradually reducing the size of the surface pond and then encapsulating the PAG tailings with NPAG tailings. Eventually the tailings embankments and top surface of the facility are given a soil cover with a thickness of at least 1.5 feet and revegetated. Stormwater conveyance channels and armoring would be used where appropriate to protect the reclaimed surface. Once surfaces are covered and stable, stormwater would be allowed to discharge downstream.

For some time after closure, the seepage collection ponds would be maintained downstream of the tailings storage facility to collect drainage from the facility. This time could vary from years to decades, depending on the alternative. There would be no discharge from the collection ponds to downstream waters, neither seepage nor stormwater that collects within the ponds. For some time the recycled water pond still would still exist within the tailings facility, and during this time collected water in the ponds could be pumped back to the recycled water pond for evaporation. Once the recycled water pond disappears, the seepage collection ponds are designed to be large enough to evaporate any collected seepage and stormwater. The seepage collection ponds are meant to stay in place until all water reporting to the ponds is of adequate quality to allow discharge downstream. At this stage, water quality from these discharges will be …?

Commented [BM28]: Please expand

Closure of the filtered tailings facility (Alternative 4) is similar but simplified by the lack of any recycled water pond. Instead, all surfaces of the PAG and NPAG facilities would be given a soil cover and revegetated. Stormwater from upstream in the watershed would be diverted around the facilities in perpetuity, and once surfaces are covered and stable, stormwater from the facilities would be allowed to discharge downstream as well.

For some time after closure (estimated to be about 5 years), the seepage collection ponds for Alternative 4 would be maintained downstream of the tailings storage facility. The seepage collection ponds are meant to stay in place until all water reporting to the ponds is of adequate quality to allow discharge downstream. Unlike Alternatives 2, 3, 5, and 6, any excess water in the seepage collection ponds during closure can't be pumped back to a recycled water pond; these ponds therefore could require active water treatment. In the long-term, the ponds are designed to be large enough to evaporate any collected seepage and stormwater.

Summary of Stormwater Controls

At no point during construction, operation, closure, or post-closure would stormwater coming into contact with tailings, ore, or processing areas be allowed to discharge downstream. After closure, precipitation falling on the tailings facilities would interact with the soil cover, not tailings. The seepage collection ponds represent a long-term commitment for managing seepage and stormwater, but eventually would either become passive systems fully evaporating collected water, or would be removed after demonstrating that collected water is of adequate quality to discharge.

Predicted Quality of Stormwater Runoff

Stormwater contacting tailing would not be released downstream; however, the potential water quality of this runoff has been estimated.

The quality of stormwater runoff from tailings and the soil cover can be predicted in several ways. In the aquifer protection permitting process, ADEQ often relies on a test called the synthetic precipitate leaching procedure (SPLP). This test measures contaminants in a slightly acidic water solution that has interacted with a rock or tailings sample. One drawback of relying solely on the SPLP test is that it is usually conducted only using fresh core or lab-created tailings samples that have not weathered. By contrast, in reality precipitation would interact with embankment tailings that could have been weathering for many decades.

Two additional methods reflect the water quality from interaction with weathered materials. As part of the geochemical characterization activities, Resolution Copper conducted a series of "barrel" tests, in which barrels of material were left exposed to natural precipitation over the course of several years. The resulting leachate from the barrels was periodically collected and analyzed. Numerous humidity cell tests also were run for long periods of time. These tests involve periodic exposure of samples to water over many weeks, even years. An estimate of the potential runoff water quality from PAG and NPAG tailings was produced, drawing on the results of these various geochemical tests (cite Eary 2018g). Runoff from NPAG tailings was calculated by combining the results of twelve humidity cell tests conducted on tailings samples representing different lithologies. Potential runoff water quality from PAG tailings (applicable to Alternative 4 only) was estimated from barrel tests conducted on filtered PAG tailings (specifically Barrel #3), supplemented with results from barrel tests conducted on paste PAG tailings (specifically Barrel #1).

Commented [BM29]: Was it weeks or years in this instance?

Natural runoff quality was also sampled by Resolution Copper, specifically during a storm even in February 2018 in the vicinity of the Near West location (specific to Alternatives 2 and 3).

Water quality results for SPLP tests, Resolution Copper estimates of runoff quality, and natural runoff are shown in table 3.7.2-4, below, and compared to the most stringent surface water quality standards (based on a hardness of 400 mg/L)[7].

All methods of estimating stormwater runoff quality suggest that both NPAG and PAG tailings may have concentrations of some constituents that are above Arizona surface water standards. As stated above, this stormwater would not be discharged to the environment at any time; the results shown in table 3.7.2-4 reinforce the need for requiring stormwater controls during operations. Post-closure runoff water quality, after the soil cover is in place and revegetated, should be similar to natural runoff water quality and concentrations above surface water quality standards would not be anticipated.

[7] Surface water quality standards are difficult to succinctly summarize, as the standards vary by specific designated use of the water body and in some cases vary by hardness of the water. For reference, table J-5 (Appendix J) summarizes all surface water standards for water bodies in the area, as well as aquifer water quality standards.

Table 3.7.2-4. Predicted stormwater runoff water quality (mg/L)

Commented [BM31]: This table is repeated, with alterations, in the sections below. Each related table should be updated with the SWQS comments here.

	Estimated runoff water quality from NPAG tailings (Alternatives 2, 3, 5, 6)**	Estimated runoff water quality from PAG tailings (Alternative 4)**	Water quality measured in natural runoff***	SPLP results for NPAG tailings****	SPLP results for PAG tailings****	Most Stringent Surface Water Standard (Gila River or Queen Creek)	Most Stringent Surface Water Standard (Ephemeral Tributaries)
Regulated Constituents							
Antimony	0.00073	0.00062	0.00027	0.003	0.003	0.030	0.747
Arsenic	0.00016	**0.576**	0.0052			0.030 (total recoverble)	0.280 (total recoverable)
Barium	0.0128	0.208	0.0128	0.0122	0.0275	98 (total recoverable)	98 (total recoverable)
Beryllium	0.0022	**0.192**	0.0005	0.002	0.002	0.0053 (dissolved)	1.867 (total recoverable)
Boron	0.0028	0.104	0.03			1 (total recoverable)	186.667 (tota recoverable)
Cadmium*	0.00097	**0.106**	0.000019	0.0002	0.0002	0.00622 (dissolved)	0.28955 (dissolved)
Chromium, Total why not III & VI?	0.00036	**9.107**	0.00095	0.006	0.006	1	-
Copper* check math and order of mag	**9.81**	**3294**	0.012	0.01	0.01	0.02928	0.08588
Fluoride	0	**424.6**	0.13			140	140
Iron	0.177	**5353.8**	0.0225	0.06	0.06	10 (dissolved)	-
Lead* check math and order of mag	0.00026	0.0095	0.0001	**0.0115**	0.003	0.01094	0.015
Manganese	0.693	**43**	0.017	0.0106	0.0313	10	130.667
Mercury				**0.0002**	**0.0002**	0.00001	0.005
Nickel* check math and order of mag	0.112	**26.39**	0.0013			0.16804	13.43579
Nitrate	0	0	3.1			3733.333	3733.333
Nitrite						233.333	233.333
Selenium	**0.0088**	**0.322**	0.00027	**0.003**	0.0043	0.002	0.033
Silver*	0.000006	**1.78**	0.000018	0.005	0.005	0.03491	0.03491

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Thallium	0.00008	**0.0177**	0.000015	0.001	0.001	0.0072	0.075
Uranium				0.001	0.001	2.8	2.8
Zinc*	0.171	**17.29**	0.0015	0.01	0.01	0.3793	3.5994
Non-Regulated Constituents							
Sulfate	264	28452	6.8	229	115	-	-
pH	**5.48**	2.13	7.59	6.53	6.72	6.5 to 9.0	--
Total Dissolved Solids				294	186	-	-

A&Ww = Aquatic and Wildlife-Warmwater; A&We = Aquatic & Wildlife-Ephemeral; FBC = Full Body Contact; PBC = Partial Body Contact; FC = Fish Consumption; AgI = Agricultural-Irrigation; AgL = Agricultural-Livestock Watering

Standards for A&Ww and A&We are for dissolved concentrations, except for selenium which is for total concentrations. All other standards are for total concentrations. Revise

All values shown in milligrams per liter

For all analyses, values below the laboratory detection limit are calculated as equal to the detection limit. There are other valid methods that could be used, such as using a zero value, or more commonly, using half the detection limit. Because surface water standards for some constituents—particularly mercury—can be extremely low, it is important to use the detection limit when looking at non-detect results. To use any lower value could yield results that meet the water quality standard, even when the detection limit was actually too high to draw this conclusion.

Some water quality standards for metals are specific to total recoverable metals or dissolved metals. Predicted results are compared to standards regardless of whether the standard specifies total or dissolved.

Shaded cell and bolded text indicate concentrations that exceed ~~above~~ at least one water quality standard

* These constituents have surface water standards that vary depending on hardness, with a maximum hardness of 400 mg/L. Calculations of hardness based on calcium and magnesium generally exceed 400 mg/L; therefore, all standards shown are based on a hardness of 400 mg/L. Is there reason to assume cadmium will be not be present in pyritized material?

** From Enchemica, Common Inputs Memo, 7/18/18, Table 3-4.

*** From Enchemica, Common Inputs Memo, 7/18/18, Table 3-2; from stormwater samples collected at Near West location.

**** NPAG results taken from "7/7A 7C Scavenger" sample from Golder 2008; PAG results taken from "7/7A 7C Cleaner" sample from Golder 2008

Commented [BM30]: Move to regulated, see R18-11-109 B of the AAC

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Commented [BM32]: This inadequately characterizes the above information. This note should also speak to whether the predicted results are total, recoverable, or dissolved

Alternative 2 – Near West – Proposed Action

POTENTIAL GROUNDWATER QUALITY IMPACTS FROM TAILINGS STORAGE FACILITY

Seepage Controls and Effectiveness

Alternative 2 includes the following seepage controls:

- Blanket drains beneath the embankment.
- Network of finger drains beneath the embankment and the tailings facility.
- Low permeability liners overlaying geologic units with relatively higher conductivities (Tertiary Perlite, Tertiary Tuff, and Pre-Cambrian Apache Group), underlaying approximately one third of the tailings footprint.
- Approximately eleven primary seepage collection dams with pump back wells. These primary seepage collection dams are covered on the upstream side with a geomembrane and built with grouted cut-off walls to interrupt flow through the alluvial channels downstream of the tailings facility.
- A 7.5-mile long and 100 feet deep grout curtain downgradient of the tailings facility.
- Twenty-one auxiliary pump back wells beyond the grout curtain with depths of approximately 200 feet.

Modeling estimates that these seepage controls would capture approximately 99% of tailings seepage and result in a total uncaptured tailings seepage to groundwater of 21 acre-feet (2.59e+7 liters) per year during the life of the mine according to an estimate with a numerical model, and 17 acre-feet (2.097e+7 liter) per year post-closure, based on the expected infiltration of precipitation. Assuming a minimal set of seepage controls only as necessary for geotechnical stability without the low permeability liner, grout curtain and auxiliary pump back wells would result in an almost 10-fold increase in seepage.

Risk of Seepage Impacting Groundwater or Surface Water Quality

Modeled results for groundwater and surface water impacts are reported by Gregory and Bayley (2019). The detailed results of the bypass seepage mixing/loading model were supplied as an Excel spreadsheet, and can be found in Garrett (2019). Table 3.7.2-5, below, presents model results for all modeled chemical constituents in the first groundwater cell along Queen Creek (cell QC-3)[8] and the ultimate, final surface water cell (Queen Creek at Whitlow Ranch Dam), for years 41, 100 and 245. This provides perspective on trends and expected conditions at the end of mining and in the long term. Table 3.7.2-5 also presents Arizona water quality standards and baseline chemistry for added perspective.

Figures K-1 through K-6 (Appendix K) illustrate model results for six chemical constituents of concern that either are regulated constituents that helped drive the required level of engineered seepage controls incorporated into the design (cadmium, selenium, antimony) or are unregulated but offer other significant

[8] Results are included in the modeling and shown in Appendix K for several washes that would receive lost seepage (Potts and Roblas Canyon), which are upgradient from cell QC-3. It is not likely that substantial groundwater exists in these alluvial channels; these modeled results are indicative of seepage itself, rather than groundwater concentrations expected in the aquifer.

perspective on water quality (nitrate, total dissolved solids, sulfate). These figures depict the model results for all ground- and surface water cells.

Modeling results for Alternative 2 indicate:

- The model results rely on the 99 percent estimated efficiency of engineered seepage controls.
- For all constituents, concentrations decrease with distance from the tailings storage facility, but increase over time.
- There are no concentrations above aquifer water quality standards for the first model cell corresponding to groundwater (cell QC-3) or subsequent downgradient cells.
- Concentrations of selenium are above the most strict surface water regulatory standard in model year 64 and onward for Queen Creek at Whitlow Ranch Dam (see Appendix K, figure K-3), despite incorporation of engineered seepage controls estimated to capture 99% of total seepage. No other constituents are modeled to have concentrations above surface water regulatory standards. The amount the model result is above the standard is very small and the uncertainty in the model does not allow a strict comparison. It can only be concluded that concentrations are expected to be near the standard.
- Sulfate and total dissolved solids are significant constituents in tailings seepage and can alter the potential use of downstream water resources, but are unregulated. Over time, sulfate concentrations in groundwater closest to the tailings storage facility are expected to rise slightly above the 250 mg/L secondary standard to 340 mg/L (see Appendix K, figure K-1).
- Most constituents increase in concentration in groundwater and surface water above existing baseline conditions.
- The risk of not being able to meet desired seepage capture efficiencies is high. While the determination of whether water quality standards would be met is under the jurisdiction of ADEQ, the disclosure undertaken by the Forest Service suggests that the high capture efficiency required of the engineered seepage controls could make meeting water quality standards under this alternative challenging. The number and types of engineered seepage controls represent significant economic and engineering challenges. Further, this high level of control incorporated in the tailings design effectively limits any opportunity for additional mitigation to be applied.

Table 3.7.2-5. Seepage Water Quality Modeling Results for Alternative 2

	Aquifer Water Quality Standard	Baseline Ground-water Quality (Well DS17-17*)	QC-3 Model Cell Year 41	QC-3 Model Cell Year 100	QC-3 Model Cell Year 245	Most Stringent Surface Water Standard	Baseline Surface Water Quality (Whitlow Ranch Dam*)	Queen Creek at WRD Modeled Surface Water Year 41	Queen Creek at WRD Modeled Surface Water Year 100	Queen Creek at WRD Modeled Surface Water Year 245
Regulated										
Antimony	0.006	0.00021	0.00026	0.00034	0.00036	0.030	0.00052	0.00054	0.00059	0.00065
Arsenic	0.05	0.0013	0.0013	0.0013	0.0014	0.030	0.00235	0.0024	0.0024	0.0024
Barium	2	0.0261	0.0263	0.0263	0.0263	98	0.0350	0.035	0.035	0.035
Beryllium	0.004	0.00100	0.00100	0.00101	0.00101	0.0053	0.0010	0.0010	0.0010	0.0010
Boron	-	0.069	0.073	0.078	0.078	1	0.057	0.059	0.062	0.066
Cadmium	0.005	0.00004	0.0001	0.0002	0.0002	0.00622	0.00005[2]	0.00007[2]	0.00015[2]	0.00020[2]
Chromium, Total	0.1	0.0019	0.0022	0.0029	0.0027	1	0.0015	0.0016	0.0020	0.0023
Copper	-	0.00076	0.004	0.004	0.003	0.02928	0.00230[2]	0.0041[2]	0.0039[2]	0.0045[2]
Fluoride	4	0.529	0.56	0.57	0.56	140	0.4	0.42	0.43	0.43
Iron	-	0.045	0.0450	0.0450	0.0450	10	0.048	0.048	0.048	0.048
Lead	0.05	0.000065	0.00008	0.00009	0.00009	0.01094	0.00008[2]	0.00008[2]	0.00009[2]	0.00010[2]
Manganese	-	0.0049	0.011	0.028	0.025	10	0.150	0.153	0.162	0.169
Mercury	0.002	N/A	N/A	N/A	N/A	0.00001	N/A	N/A	N/A	N/A
Nickel	0.1	0.0027	0.003	0.005	0.005	0.16804	0.0027[2]	0.0030[2]	0.0041[2]	0.0050[2]
Nitrate	10	0.38[1]	0.43	0.46	0.45	3733.333	1.900	1.93	1.94	1.97
Nitrite	1	N/A	N/A	N/A	N/A	233.333	N/A	N/A	N/A	N/A
Selenium	0.05	0.0009	0.002	0.005	0.004	0.002	0.0007	0.0012	**0.0027**	**0.0038**
Silver	-	0.000036	0.0003	0.0009	0.0007	0.03491	0.000036	0.00016	0.00049	0.00071
Thallium	0.002	0.00003	0.00006	0.00009	0.00008	0.0072	0.000030	0.00004	0.00006	0.00008
Uranium	-	N/A	N/A	N/A	N/A	2.8	N/A	N/A	N/A	N/A
Zinc	-	0.005	0.018	0.045	0.039	0.3793	0.0030[2]	0.0088[2]	0.0238[2]	0.0353[2]
Non-Regulated										
Sulfate	-	173	186	208	209	-	136	144	154	168
pH	-	N/A	N/A	N/A	N/A	-	N/A	N/A	N/A	N/A

Total Dissolved Solids	-	589	614	652	652	-	546	561	579	603

* Results shown represent median values from water quality measurements

[1]No available data for well DS17-17. NO3-N value calculated as median of three samples collected from Bear Tank and Benson Springs between November 2014 and March 2015

[2]Standards are hardness dependent and were calculated using lowest (most stringent) hardness value recorded for Whitlow Ranch Dam (307 mg/L CaCO3 on 8/25/2017)

N/A= not analyzed in seepage modeling

Shaded cell and bolded text indicate concentrations above water quality standard

Commented [BM33]: See comment in above table

Alternative 3 – Near West – Thin-Lift

POTENTIAL GROUNDWATER QUALITY IMPACTS FROM TAILINGS STORAGE FACILITY

Seepage Controls and Effectiveness

Alternative 3 includes all seepage controls listed for Alternative 2, plus a low permeability liner underlaying the segregated PAG tailings.

Modeling estimates that these seepage controls would capture approximately 99.5% of tailings seepage and result in a total uncaptured tailings seepage to groundwater of 3 acre-feet (3.7e+6 liters) per year according to an estimate with a numerical model, and 25 acre-feet (3.084e+7 liters) per -year post-closure, based on the expected infiltration of precipitation. Assuming a simple set of seepage controls only as necessary for geotechnical stability without low permeability liner, grout curtain and auxiliary pump back wells would result in an about 25-fold increase in seepage.

Risk of Seepage Impacting Groundwater or Surface Water Quality

Modeled results for groundwater and surface water impacts are reported by Gregory and Bayley (2019). The detailed results of the bypass seepage mixing/loading model were supplied as an Excel spreadsheet, and can be found in Garrett (2019). Table 3.2.7-7, below, presents model results for all modeled chemical constituents in the first groundwater cell along Queen Creek (cell QC-3)[9] and the ultimate, final surface water cell (Queen Creek at Whitlow Ranch Dam), for years 41, 100 and 245. This provides perspective on trends and expected conditions at the end of mining and in the long term. Table 3.7.2-6 also presents Arizona water quality standards and baseline chemistry for added perspective.

Figures K-7 through K-12 (Appendix K) illustrate model results for the six constituents of concern.

Modeling results for Alternative 3 indicate:

- The model results rely on the 99.5 percent estimated efficiency of engineered seepage controls.
- For all constituents, concentrations decrease with distance from the tailings storage facility, but increase over time.
- No chemical constituent are anticipated in concentrations above groundwater or surface water standards.
- Selenium and cadmium are increased slightly above baseline conditions in groundwater and surface water (see Appendix K, figures K-9 and K-10).
- The risk of not being able to meet desired seepage capture efficiencies is high. While the determination of whether water quality standards would be met is under the jurisdiction of ADEQ, the disclosure undertaken by the Forest Service suggests that the high capture efficiency required of the engineered seepage controls could make meeting water quality standards under this alternative challenging. The number and types of engineered seepage controls represent significant economic and engineering challenges. Further, this high level of control incorporated in the tailings design effectively limits any opportunity for additional mitigation to be applied.

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[9] Similar to Alternative 2, results are included in the modeling and shown in Appendix K for several washes that would receive lost seepage (Potts and Roblas Canyons), which are upgradient from cell QC-3. It is not likely that substantial groundwater exists in these alluvial channels; these modeled results are indicative of seepage itself, rather than groundwater concentrations expected in the aquifer.

Table 3.7.2-6. Seepage Water Quality Modeling Results for Alternative 3

	Aquifer Water Quality Standard	Baseline Ground-water Quality (Well DS17-17*)	QC-3 Model Cell Year 41	QC-3 Model Cell Year 100	QC-3 Model Cell Year 245	Most Stringent Surface Water Standard	Baseline Surface Water Quality (Whitlow Ranch Dam*)	Queen Creek at WRD Modeled Surface Water Year 41	Queen Creek at WRD Modeled Surface Water Year 100	Queen Creek at WRD Modeled Surface Water Year 245
Regulated										
Antimony	0.006	0.00021	0.00021	0.00021	0.00022	0.030	0.00052	0.00052	0.00052	0.00053
Arsenic	0.05	0.0013	0.0013	0.0013	0.0013	0.030	0.00235	0.0024	0.0024	0.0024
Barium	2	0.0261	0.0261	0.0261	0.0261	98	0.035	0.035	0.035	0.035
Beryllium	0.004	0.00100	0.00100	0.00100	0.00100	0.0053	0.0010	0.0010	0.0010	0.0010
Boron	-	0.069	0.069	0.069	0.069	1	0.057	0.057	0.057	0.057
Cadmium	0.005	0.00004	0.0000	0.0000	0.0001	0.00622	0.00005[2]	0.00005[2]	0.00005[2]	0.00006[2]
Chromium, Total	0.1	0.0019	0.0019	0.0019	0.0020	1	0.0015	0.0015	0.0015	0.0015
Copper	-	0.00076	0.001	0.001	0.001	0.02928	0.00230[2]	0.0023[2]	0.0024[2]	0.0024[2]
Fluoride	4	0.529	0.53	0.53	0.53	140	0.4	0.41	0.41	0.41
Iron	-	0.045	0.0450	0.0450	0.0450	10	0.048	0.048	0.048	0.048
Lead	0.05	0.000065	0.00007	0.00007	0.00007	0.01094	0.00008[2]	0.00008[2]	0.00008[2]	0.00008[2]
Manganese	-	0.0049	0.005	0.005	0.007	10	0.150	0.150	0.150	0.151
Mercury	0.002	N/A	N/A	N/A	N/A	0.00001	N/A	N/A	N/A	N/A
Nickel	0.1	0.0027	0.003	0.003	0.003	0.16804	0.0027[2]	0.0027[2]	0.0027[2]	0.0028[2]
Nitrate	10	0.38[1]	0.38	0.38	0.39	3733.333	1.900	1.90	1.90	1.90
Nitrite	1	N/A	N/A	N/A	N/A	233.333	N/A	N/A	N/A	N/A
Selenium	0.05	0.0009	0.001	0.001	0.001	0.002	0.0007	0.0007	0.0007	0.0009
Silver	-	0.000036	0.0000	0.0001	0.0001	0.03491	0.000036	0.00004	0.00005	0.00007
Thallium	0.002	0.00003	0.00003	0.00003	0.00004	0.0072	0.000030	0.00003	0.00003	0.00003
Uranium	-	N/A	N/A	N/A	N/A	2.8	N/A	N/A	N/A	N/A
Zinc	-	0.005	0.005	0.006	0.008	0.3793	0.0030[2]	0.0030[2]	0.0034[2]	0.0045[2]
Non-Regulated										
Sulfate	-	173	173	174	176	-	136	136	136	138
pH	-	N/A	N/A	N/A	N/A	-	N/A	N/A	N/A	N/A

Total Dissolved Solids	-	589	589	590	594	-	546	546	546	549

- * Results shown represent median values from water quality measurements
- [1]No available data for well DS17-17. NO3-N value calculated as median of three samples collected from Bear Tank and Benson Springs between November 2014 and March 2015
- [2]Standards are hardness dependent and were calculated using lowest (most stringent) hardness value recorded for Whitlow Ranch Dam (307 mg/L CaCO3 on 8/25/2017)
- N/A= not analyzed in seepage modeling

Commented [BM34]: See comments in tables above re: SWQS

Alternative 4 – Silver King

POTENTIAL GROUNDWATER QUALITY IMPACTS FROM TAILINGS STORAGE FACILITY

Seepage Controls and Effectiveness

Alternative 4 includes the following seepage controls:

- Blanket drains and/or finger drains beneath the embankment and the tailings facility.
- Lined collection ditches and collection ponds that cut off the alluvium.
- Grouting of fractures in the bedrock foundation.
- Pump back wells.
- A low permeability liner was considered not deemed feasible for Alternative 4 (KCB 2019b).

Based on the professional judgement of the design engineers, it is estimated that these seepage controls would capture approximately 90% of tailings seepage and result in total uncaptured tailings seepage to groundwater of up 9 to 17 acre-feet (2.097e+7) per year during life of mine and from 15 to 32 acre-feet (3.947e+7 liters) per year post-closure. The increase in seepage is the result of infiltration of precipitation gradually increasing the moisture content of the filtered tailings.

Risk of Seepage Impacting Groundwater or Surface Water Quality

Modeled results for groundwater and surface water impacts are reported by Gregory and Bayley(2019). The detailed results of the bypass seepage mixing/loading model were supplied as an Excel spreadsheet, and can be found in Garrett (2019). Table 3.7.2-7, below, presents model results for all modeled chemical constituents in the first groundwater cell along Queen Creek (cell QC-1)[10] and the ultimate surface water cell (Queen Creek at Whitlow Ranch Dam), for years 41, 100 and 245. This provides perspective on trends and expected conditions at the end of mining and in the long term. Table 3.7.2-7 also presents Arizona water quality standards and baseline chemistry for added perspective.

Figures K-13 through K-18 (Appendix K) illustrate model results for the six constituents of concern.

Modeling results for Alternative 4 indicate:

- The model results rely on the 90 percent estimated efficiency of engineered seepage controls.
- For all constituents, concentrations decrease with distance from the tailings storage facility, but increase over time.
- There are no concentrations above aquifer water quality standards for the first model cell corresponding to groundwater (cell QC-1) or subsequent downgradient cells. Note that although Gregory and Bayley (2019) report that concentrations are above groundwater standards for Alternative 4, their conclusion is based upon the interpretation of first groundwater occurring in the alluvial channels very close to the tailings storage facility. As noted above, it is not likely that groundwater actually occurs until further downgradient, near Queen Creek.
- Concentrations of selenium are above the most strict surface water regulatory standard in model years 59 and onward for Queen Creek at Whitlow Ranch Dam (see Appendix K, figure K-15), despite incorporation of engineered seepage controls estimated to capture 90% of total seepage. No other constituents are modeled to have concentrations above surface water regulatory

[10] Results are included in the modeling and shown in Appendix K for several washes that would receive lost seepage (Happy Camp Wash East and West, Silver King Wash, Potts Canyon), which are upgradient from cell QC-1. It is not likely that substantial groundwater exists in these alluvial channels; these modeled results are indicative of seepage itself, rather than groundwater concentrations expected in the aquifer.

standards. The amount the model result is above the standard is very small and the uncertainty in the model does not allow a strict comparison. It can only be concluded that concentrations are expected to be near the standard.

Commented [BM35]: May need to revise

- Sulfate and total dissolved solids are significant constituents in tailings seepage and can alter the potential use of downstream water resources, but are unregulated. Over time, sulfate concentrations in groundwater closest to the tailings storage facility are expected to rise slightly above the 250 mg/L secondary standard to 284 mg/L (see Appendix K, figure K-13).

Commented [BM36]: Indirectly regulated

- Most constituents increase in concentration in groundwater and surface water above existing baseline conditions.
- The risk of not being able to meet desired seepage capture efficiencies is moderate and less than Alternatives 2 and 3. Depending on further site characterization, there may be opportunity for additional mitigation to be applied.

Table 3.7.2-7. Seepage Water Quality Modeling Results for Alternative 4

	Aquifer Water Quality Standard	Baseline Ground-water Quality (Well DS17-17*)	QC-3 Model Cell Year 41	QC-3 Model Cell Year 100	QC-3 Model Cell Year 245	Most Stringent Surface Water Standard	Baseline Surface Water Quality (Whitlow Ranch Dam*)	Queen Creek at WRD Modeled Surface Water Year 41	Queen Creek at WRD Modeled Surface Water Year 100	Queen Creek at WRD Modeled Surface Water Year 245
Regulated										
Antimony	0.006	0.00021	0.00022	0.00052	0.00074	0.030	0.00052	0.00052	0.00068	0.00080
Arsenic	0.05	0.0013	0.0013	0.0016	0.0018	0.030	0.00235	0.0024	0.0025	0.0026
Barium	2	0.0261	0.0263	0.0263	0.0264	98	0.0350	0.035	0.035	0.035
Beryllium	0.004	0.00100	0.00102	0.00102	0.00104	0.0053	0.0010	0.0010	0.0010	0.0010
Boron	-	0.069	0.069	0.082	0.091	1	0.057	0.057	0.064	0.069
Cadmium	0.005	0.00004	0.0000	0.0003	0.0004	0.00622	0.00005[2]	0.00005[2]	0.00016[2]	0.00023[2]
Chromium, Total	0.1	0.0019	0.0019	0.0026	0.0030	1	0.0015	0.0015	0.0019	0.0021
Copper	-	0.00076	0.003	0.004	0.006	0.02928	0.00230[2]	0.0035[2]	0.0038[2]	0.0049[2]
Fluoride	4	0.529	0.53	0.56	0.58	140	0.4	0.41	0.42	0.43
Iron	-	0.045	0.0450	0.0450	0.0450	10	0.048	0.048	0.048	0.048
Lead	0.05	0.000065	0.00007	0.00012	0.00015	0.01094	0.00008[2]	0.00008[2]	0.00010[2]	0.00012[2]
Manganese	-	0.0049	0.010	0.060	0.088	10	0.150	0.153	0.178	0.194
Mercury	0.002	N/A	N/A	N/A	N/A	0.00001	N/A	N/A	N/A	N/A
Nickel	0.1	0.0027	0.004	0.007	0.009	0.16804	0.0027[2]	0.0031[2]	0.0047[2]	0.0060[2]
Nitrate	10	0.38[1]	0.40	0.40	0.42	3733.333	1.900	1.91	1.91	1.92
Nitrite	1	N/A	N/A	N/A	N/A	233.333	N/A	N/A	N/A	N/A
Selenium	0.05	0.0009	0.001	0.006	0.008	0.002	0.0007	0.0007	**0.0031**	**0.0046**
Silver	-	0.000036	0.0000	0.0009	0.0014	0.03491	0.000036	0.00004	0.0005	0.00074
Thallium	0.002	0.00003	0.00003	0.00009	0.00012	0.0072	0.000030	0.00003	0.00006	0.00008
Uranium	-	N/A	N/A	N/A	N/A	2.8	N/A	N/A	N/A	N/A
Zinc	-	0.005	0.006	0.053	0.081	0.3793	0.0030[2]	0.0036[2]	0.0281[2]	0.0428[2]
Non-Regulated										
Sulfate	-	173	175	212	241	-	136	137	156	172

pH	-	N/A	N/A	N/A	N/A	-	N/A	N/A	N/A	N/A
Total Dissolved Solids	-	589	592	647	688	-	546	547	576	598

* Results shown represent median values from water quality measurements

[1]No available data for well DS17-17. NO3-N value calculated as median of three samples collected from Bear Tank and Benson Springs between November 2014 and March 2015

[2]Standards are hardness dependent and were calculated using lowest (most stringent) hardness value recorded for Whitlow Ranch Dam (307 mg/L CaCO3 on 8/25/2017)

N/A= not analyzed in seepage modeling

Shaded cell and bolded text indicate concentrations above water quality standard

Commented [BM37]: See above comments in previous tables on SWQS

Alternative 5 – Peg Leg

POTENTIAL GROUNDWATER QUALITY IMPACTS FROM TAILINGS STORAGE FACILITY

Seepage Controls and Effectiveness

Alternative 5 includes the following seepage controls:

- Blanket drains and/or finger drains beneath the embankment and the tailings facility.
- Lined collection ditches and collection ponds.
- Pump back wells.
- HDPE lining of recycled water pond area (300 acres), where recycled water pond is in contact with native materials.
- Engineered low-permeability layers for PAG cell.
- Synthetic lining of PAG cell base and embankments.

Modeling estimates that these seepage controls would capture approximately 84% of tailings seepage and result in total uncaptured tailings seepage to groundwater of up to 261 acre-feet (3.219e+8 liters) per year, and 258 acre-feet (3.182e+8 liters) per year post-closure.

Risk of Seepage Impacting Groundwater or Surface Water Quality

Modeled results for groundwater and surface water impacts are reported by Gregory and Bayley (2019). The detailed results of the bypass seepage mixing/loading model were supplied as an Excel spreadsheet, and can be found in Garrett (2019). Table 3.7.2-8, below, presents model results for all modeled chemical constituents for cells in the first groundwater cell along Donnelly Wash (cell DW-2) and the ultimate surface water cell (Gila River below Donnelly Wash), for years 41, 100 and 245. This provides perspective on trends and expected conditions at the end of mining and in the long term. Table 3.7.2-8 also presents Arizona water quality standards and baseline chemistry for added perspective.

Figures K-19 through K-24 (Appendix K) illustrate model results for the six constituents of concern.

Modeling results for Alternative 5 indicate:

- The model results rely on the 84 percent estimated efficiency of engineered seepage controls.
- For all constituents, concentrations decrease with distance from the tailings storage facility, but increase over time.
- No chemical constituent are anticipated in concentrations above groundwater or surface water standards. Nitrate is present in concentrations above aquifer water quality standards, but this is due to background nitrate concentrations and not seepage from the facility. Note also that in year 245, selenium just reaches the aquifer water quality standard but is not above it.
- Sulfate and total dissolved solids are significant constituents in tailings seepage and can alter the potential use of downstream water resources, but are unregulated. Over time, sulfate concentrations in groundwater closest to the tailings storage facility are expected to rise substantially above the 250 mg/L secondary standard to 594 mg/L (see Appendix K, figure K-19).
- Most constituents increase in concentration in groundwater and surface water above existing baseline conditions.
- The risk of not being able to meet desired seepage capture efficiencies is moderate and less than Alternatives 2 and 3. Depending on further site characterization, there may be opportunity for additional mitigation to be applied.

Commented [BM38]: May need to revise, see above comments

Table 3.7.2-8. Seepage Water Quality Modeling Results for Alternative 5

	Aquifer Water Quality Standard	Baseline Ground-water Quality (Tea Cup Well*)	DW-2 Model Cell Year 41	DW-2 Model Cell Year 100	DW-2 Model Cell Year 245	Most Stringent Surface Water Standard	Baseline Surface Water Quality (Gila River below Donnelly Wash**)	Gila River below Donnelly Wash Modeled Surface Water Year 41	Gila River below Donnelly Wash Modeled Surface Water Year 100	Gila River below Donnelly Wash Modeled Surface Water Year 245
Regulated										
Antimony	0.006	0.00003	0.00003	0.00044	0.00214	0.030	0.00023	0.00023	0.00023	0.00025
Arsenic	0.05	0.0021	0.0021	0.0022	0.0032	0.030	0.00889	0.0089	0.0089	0.0089
Barium	2	0.0428	0.0428	0.0442	0.0483	98	0.0826	0.083	0.083	0.083
Beryllium	0.004	0.0010	0.00100	0.00104	0.00202	0.0053	0.0017	0.0017	0.0017	0.0017
Boron	-	0.082	0.082	0.112	0.205	1	0.190	0.190	0.190	0.191
Cadmium	0.005	0.00004	0.0000	0.0006	0.0026	0.00622	0.00006[2]	0.00006[2]	0.00006[2]	0.00009[2]
Chromium, Total	0.1	0.0019	0.0019	0.0050	0.0137	1	0.0020	0.0020	0.0020	0.0021
Copper	-	0.00330	0.003	0.034	1.035	0.02928	0.00408[2]	0.0041[2]	0.0041[2]	0.0099[2]
Fluoride	4	0.68	0.68	0.90	1.71	140	0.987	0.99	0.99	1.00
Iron	-	0.045	0.0450	0.0452	0.0470	10	0.056	0.056	0.056	0.056
Lead	0.05	0.002630	0.00263	0.00274	0.00321	0.01094	0.00015[2]	0.00015[2]	0.00015[2]	0.00016[2]
Manganese	-	0.0049	0.005	0.075	0.580	10	0.028	0.028	0.028	0.033
Mercury	0.002	N/A	N/A	N/A	N/A	0.00001	N/A	N/A	N/A	N/A
Nickel	0.1	0.0027	0.003	0.012	0.085	0.16804	0.0023[2]	0.0023[2]	0.0023[2]	0.0030[2]
Nitrate	10	**15.20[1]**	**15.26**	**15.53**	**16.34**	3733.333	0.091	0.09	0.09	0.11
Nitrite	1	N/A	N/A	N/A	N/A	233.333	N/A	N/A	N/A	N/A
Selenium	0.05	0.0011	0.001	0.013	0.050	0.002	0.0004	0.0004	0.0004	0.0010
Silver	-	0.000036	0.0000	0.0026	0.0100	0.03491	0.000061	0.00006	0.00006	0.00018
Thallium	0.002	0.00003	0.00003	0.00024	0.00073	0.0072	0.000080	0.00008	0.00008	0.00009
Uranium	-	N/A	N/A	N/A	N/A	2.8	N/A	N/A	N/A	N/A
Zinc	-	0.016	0.016	0.132	0.560	0.3793	0.0050[2]	0.0050[2]	0.0050[2]	0.0109[2]
Non-Regulated										
Sulfate	-	59	59	138	594	-	159	59	159	164

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pH	-	N/A	N/A	N/A	N/A	-	N/A	N/A	N/A	N/A
Total Dissolved Solids	-	523	523	648	1,338	-	776	776	776	783

* Assumed concentrations are based on single sample collected on 27 September 2017 and are therefore approximate

**Assumed concentrations are based on single sample collected on 13 November 2018 and are therefore approximate

[1]NO3-N concentration shown is above its standard; additional water quality monitoring is required to determine if value is representative of aquifer water quality or due to localized contamination

[2] Standards are hardness dependent and were calculated using a hardness value of 290 mg/L CaCO3 (from sample collected on 13 November 2018)

N/A= not analyzed in seepage modeling

Shaded cell and bolded text indicate concentrations above water quality standard

Commented [BM39]: See above table comments on SWQS

Alternative 6 – Skunk Camp

POTENTIAL GROUNDWATER QUALITY IMPACTS FROM TAILINGS STORAGE FACILITY

Seepage Controls and Effectiveness

Alternative 6 includes the following seepage controls:

- Blanket drains and/or finger drains beneath the embankment and the tailings facility.
- A grout curtain to a depth of 100 feet.
- Pump back wells to a depth of 100 feet.
- Engineered low-permeability layers for PAG cells.
- Seepage collection ponds with cut-offs, and grout curtains.

Modeling estimates that these seepage controls would capture approximately 90% of tailings seepage and result in total uncaptured tailings seepage to groundwater of up to 70 to 180 acre-feet (2.22e+8 liters) per year, and 258 acre-feet (3.182e+8 liters) per year post-closure.

Risk of Seepage Impacting Groundwater or Surface Water Quality

Modeled results for groundwater and surface water impacts are reported by Gregory and Bayley (2019). The detailed results of the bypass seepage mixing/loading model were supplied as an Excel spreadsheet, and can be found in Garrett (2019). Table 3.7.2-9, below, presents model results for all modeled chemical constituents in the first groundwater cell (cell DS-1)and the ultimate surface water cell (Gila River below Dripping Springs Wash), for years 41, 100 and 245. This provides perspective on trends and expected conditions at the end of mining and in the long term. Table 3.7.2-9 also presents Arizona water quality standards and baseline chemistry for added perspective.

Figures K-25 through K-30 (Appendix K) illustrate model results for the six constituents of concern.

Modeling results for Alternative 6 indicate:

- The model results rely on the 90 percent estimated efficiency of engineered seepage controls.
- For all constituents, concentrations decrease with distance from the tailings storage facility, but increase over time.
- No chemical constituent are anticipated in concentrations above groundwater or surface water standards.
- Sulfate and total dissolved solids are significant constituents in tailings seepage and can alter the potential use of downstream water resources, but are unregulated. Over time, sulfate concentrations in groundwater closest to the tailings storage facility are expected to rise slightly above the 250 mg/L secondary standard to 385 mg/L (see Appendix K, figure K-25).
- Most constituents increase in concentration in groundwater and surface water above existing baseline conditions.
- The risk of not being able to meet desired seepage capture efficiencies is moderate and less than Alternatives 2 and 3. Depending on further site characterization, there may be opportunity for additional mitigation to be applied.

Commented [BM40]: May need to update, see above comments

Table 3.7.2-9. Seepage Water Quality Modeling Results for Alternative 6

	Aquifer Water Quality Standard	Baseline Ground-water Quality (Skunk Camp Well*)	DS-1 Model Cell Year 41	DS-1 Model Cell Year 100	DS-1 Model Cell Year 245	Most Stringent Surface Water Standard	Baseline Surface Water Quality (Gila River below Dripping Springs Wash*)	Gila River below Dripping Springs Wash Modeled Surface Water Year 41	Gila River below Dripping Springs Wash Modeled Surface Water Year 100	Gila River below Dripping Springs Wash Modeled Surface Water Year 245
Regulated										
Antimony	0.006	0.00023	0.00091	0.00128	0.00162	0.030	0.00023	0.00024	0.00025	0.00025
Arsenic	0.05	0.0003	0.0003	0.0005	0.0011	0.030	0.00861	0.0086	0.0086	0.0086
Barium	2	0.0038	0.0073	0.0081	0.0078	98	0.0749	0.075	0.075	0.075
Beryllium	0.004	0.0017	0.00171	0.00171	0.00171	0.0053	0.0017	0.0017	0.0017	0.0017
Boron	-	0.026	0.076	0.100	0.109	1	0.196	0.197	0.197	0.197
Cadmium	0.005	0.00006	0.0011	0.0015	0.0014	0.00622	0.00006[1]	0.00008[1]	0.00009[1]	0.00009[1]
Chromium, Total	0.1	0.0020	0.0077	0.0098	0.0087	1	0.0020	0.0021	0.0021	0.0021
Copper	-	0.00165	0.038	0.051	0.044	0.02928	0.00207[1]	0.0026[1]	0.0029[1]	0.0028[1]
Fluoride	4	0.232	0.78	0.96	0.87	140	1.0	1.04	1.04	1.04
Iron	-	0.056	0.0563	0.0564	0.0564	10	0.071	0.071	0.071	0.071
Lead	0.05	0.000140	0.00031	0.00040	0.00045	0.01094	0.00014[1]	0.00014[1]	0.00014[1]	0.00015[1]
Manganese	-	0.0034	0.122	0.170	0.156	10	0.029	0.031	0.032	0.032
Mercury	0.002	N/A	N/A	N/A	N/A	0.00001	N/A	N/A	N/A	N/A
Nickel	0.1	0.0023	0.015	0.020	0.022	0.16804	0.0023[1]	0.0025[1]	0.0026[1]	0.0026[1]
Nitrate	10	1.34	1.82	1.95	1.91	3733.333	0.305	0.31	0.32	0.31
Nitrite	1	N/A	N/A	N/A	N/A	233.333	N/A	N/A	N/A	N/A
Selenium	0.05	0.0004	0.022	0.030	0.028	0.002	0.0004	0.0007	0.0009	0.0009
Silver	-	0.000061	0.0050	0.0069	0.0059	0.03491	0.000061	0.00014	0.00018	0.00016
Thallium	0.002	0.00008	0.00042	0.00053	0.00047	0.0072	0.000080	0.00009	0.00009	0.00009
Uranium	-	N/A	N/A	N/A	N/A	2.8	N/A	N/A	N/A	N/A
Zinc	-	0.224	0.445	0.538	0.518	0.3793	0.00550[1]	0.0085[1]	0.0103[1]	0.0099[1]
Non-Regulated										

Sulfate	-	54	196	365	385	-	100	102	105	105
pH	-	N/A	N/A	N/A	N/A	-	N/A	N/A	N/A	N/A
Total Dissolved Solids	-	327	575	830	846	-	702	706	710	711

* Assumed concentrations are based on single sample collected on 9 November 2018 and are therefore approximate

[1]Standards are hardness dependent and were calculated using a hardness value of 242 mg/L CaCO3 (from sample collected on 9 November 2018)

N/A= not analyzed in seepage modeling

Commented [BM41]: See comment in above tables re: SWQS

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Other Water Quality Concerns

PREDICTED REDUCTIONS IN ASSIMILATIVE CAPACITY

The calculated reductions in assimilative capacity[11] are shown in Table 3.7.2-10. For Alternatives 2 and 4, since concentrations for selenium were already predicted to be above the surface water quality standards, by definition no assimilative capacity remains. While Alternative 3 seepage does not use up more than twenty percent of the assimilative capacity in Queen Creek, the Gila River seepage discharges utilize more than twenty percent of the assimilative capacity for copper (Alternative 5) and selenium (Alternatives 5 and 6).

Commented [BM42]: Assimilative capacity calculations have been disputed between ADEQ and RCM with the ADEQ capacity being smaller than the RCM outcome; the capacity discussed here may reflect the larger modeled capacity

Table 3.7.2-10. Predicted changes in assimilative capacity due to seepage entering surface waters

Alternative	Receiving water	Remaining assimilative capacity after seepage enters surface water
Alternative 2	Queen Creek at Whitlow Ranch Dam	Selenium (0%); the selenium concentration is above the numeric surface water quality standard
Alternative 3	Queen Creek at Whitlow Ranch Dam	No changes in assimilative capacity greater than 20 percent are anticipated
Alternative 4	Queen Creek at Whitlow Ranch Dam	Selenium (0%); the selenium concentration is above the numeric surface water quality standard
Alternative 5	Gila River below Donnelly Wash	Copper (77%); Selenium (63%)
Alternative 6	Gila River below Dripping Springs Wash	Selenium (67%)

For full calculations, see Newell and Garrett 2018

POTENTIAL IMPACTS ON IMPAIRED WATERS

As noted, in the project area Queen Creek is currently considered impaired for copper and the Gila River is considered impaired for suspended sediment.

Seepage from Alternatives 2, 3, and 4 would represent an additional dissolved copper load to Queen Creek.

Given the stormwater controls put in place during operation and the long-term reclamation after closure, it is unlikely that Alternatives 5 or 6 would contribute to suspended sediment in the Gila River.

PERSISTENCE OF PROCESSING CHEMICALS IN TAILINGS

In order to extract concentrated copper and molybdenum using flotation, Resolution Copper would add a series of substances or reagents during processing. If these substances were to persist in the processing water, they have the potential to be released to the environment along with seepage from the tailings

[11] For full details of the assimilative capacity calculations, see Newell and Garrett 2018.

storage facilities. Six reagents expected to be used in the processing facility were analyzed (cite Tetra Tech 2018).

- AERO® 8989. This substance renders the copper minerals hydrophobic, causing them to attach to air bubbles blown into the flotation tank. The copper-molybdenum concentrate froth then floats to the top of the tank and is skimmed off. The majority of the AERO® 8989 exits the process with the copper-molybdenum concentrate. This concentrate gets thickened and separated into copper concentrate and molybdenum concentrate and sent off site for additional processing. Water recovered from the concentrate thickeners is recycled back to the processing plant. While some small amounts may persist in the tailings stream, there is no pathway for a substantial release of AERO® 8989 to the environment.

- Diesel. Diesel acts similarly to AERO® 8989 but for molybdenum minerals. Water recovered from the concentrate thickeners is recycled back to the processing plant. As with AERO® 8989, while some small amounts may persist in the tailings stream, there is no pathway for a substantial release of diesel to the environment.

- Sodium isopropyl xanthate (SIPX) acts similarly to AERO® 8989 and diesel but attaches to pyrite and sulfide minerals and renders them hydrophobic. SIPX is used later in the process, after copper and molybdenum concentrates have been removed, in order to separate the PAG and NPAG tailings streams. The majority of this reagent would enter the tailings storage facility with the PAG tailings stream.

  Any water recovered in the recycled water pond would potentially contain SIPX and would be recycled back to the processing plant. Some SIPX remains entrained with the PAG tailings and therefore has the potential to contribute to seepage water quality. The breakdown of SIPX yields xanthate and carbon disulfide as two major byproducts. Xanthate decomposes as well as adsorbs; depending on the temperature the half-life can range from less than an hour to almost four months (Eary 2018h). At the concentrations being considered and the likely temperatures, xanthate is unlikely to survive long enough to be detectable in any lost seepage.

  Most of the carbon disulfide generated is expected to be volatilized as tailings pass through the spigots and are deposited in the facility. The carbon disulfide that remains decomposes with a half-life ranging from roughly 6 months to a year. Given that the transit times for seepage to reach aquifers is estimated in the range of decades (cite Groenendyk and Bayley 2018b), carbon disulfide is unlikely to survive long enough to be detectable in any lost seepage.

Commented [BM43]: What does this decompose into in the atmosphere?

- Methyl isobutyl carbinol (MIBC). MIBC is used to lower the surface tension of the water, thus strengthening the air bubbles in the flotation tank. MIBC is used during concentration of copper and molybdenum and during separation of the PAG and NPAG tailings streams. Most MIBC would volatize, and the MIBC that remains degrades relatively quickly, at about 14 percent per day (cite Tetra Tech 2018). MIBC is unlikely to survive long enough to be detectable in any lost seepage.

- Sodium hydrogen sulfide. This substance is used to separate copper from molybdenum concentrate by causing copper minerals to sink, while molybdenum concentrate remains in flotation. Water recovered from the concentrate thickeners is recycled back to the processing plant. There is no pathway for a substantial release of sodium hydrogen sulfide to the environment.

- Magnafloc 155. This substance is a flocculant, used to cause particles to combine into large groups and therefore settle more readily. This substance would be present in the PAG and NPAG tailings streams and in the copper and molybdenum concentrates. Specific information on the degradation of Magnafloc 155 is lacking. Some evidence exists that exposure to sunlight and physical processing are both likely to cause degradation. The potential for Magnafloc 155 to persist in tailings seepage is unclear, but as the purpose of using Magnafloc is to bind with solid particles it would not be expected to have substantial mobility.

PRESENCE OF ASBESTIFORM MINERALS

[Note to reviewers: This topic is currently being investigated.]

TECHNOLOGICALLY-ENHANCED NATURALLY-OCCURRING RADIOACTIVE MATERIALS (TENORM)

[Note to reviewers: This topic is currently being investigated.]

3.7.2.5 Cumulative Effects

[Note to reviewers: Please review cumulative effects analysis in separate memorandum.]

3.7.2.6 Mitigation Effectiveness

The Forest Service is in the process of developing a robust mitigation plan to avoid, minimize, rectify, reduce, or compensate for resource impacts that have been identified during the process of preparing this EIS. Appendix F contains descriptions of mitigation concepts being considered and known to be effective, as of publication of the DEIS. Appendix F also contains descriptions of monitoring that would be needed to identify potential impacts and mitigation effectiveness. As noted in chapter 2 (section 2.3), the full suite of mitigation would be contained in the FEIS, required by the ROD, and ultimately included in the final GPO approved by the Forest Service. Public comment on the EIS, and in particular appendix F, will inform the final suite of mitigations.

This section contains an assessment of the effectiveness of design features from the GPO and mitigation and monitoring measures found in appendix F that are applicable to groundwater and surface water quality.

Mitigation Measures Applicable to Groundwater and Surface Water Quality

[Note to reviewers: This section is pending completion of mitigation discussions]

Mitigation Effectiveness and Impacts

[Note to reviewers: This section is pending completion of mitigation discussions]

Unavoidable Adverse Effects

[Note to reviewers: This section is pending completion of mitigation discussions]

3.7.2.7 Other Required Disclosures

Short-Term Uses and Long-Term Productivity

[Note to reviewers: This section is pending completion of mitigation discussions]

Irreversible and Irretrievable Commitment of Resources

[Note to reviewers: This section is pending completion of mitigation discussions]

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